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Gross, histological and scanning electron morphological studies on the nasal turbinates of one humped camel (*Camelus dromedarius*)

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The camel nasal turbinates include the ethmoturbinates and maxilloturbinates (ventral nasal concha). This study was conducted on amputated heads of camel fetuses and adult dromedary camels of both sexes. During the prenatal period, the ethmoturbinates are found from the earliest stage of development. They were seven in number; (I - VII) extended to the perpendicular plate of the ethmoid bone and the nasal septum. During the post-natal period, the dorsal and middle nasal conchae (DNC, MNC) enclosed the dorsal, middle conchal sinuses respectively while ventral nasal concha (VNC) had recess and bulla instead. The ethmoidal conchae (EC) located only in the nasal fundus. SEM showed wavy like appearance of non-keratinized squamous cells with micro ridges in the most rostral part of DNC and VNC while, in the middle third, clarified a dominance of goblet and ciliated cells. In the EC, the olfactory epithelium revealed olfactory vesicles with radiating cilia beside non-ciliated supporting cells. Histologically, the stratified squamous epithelium lining the turbinates in the nasal vestibule was gradually changed into pseudostratified columnar ciliated in the respiratory region. The morphometric investigation revealed that the outer covering mucosa of the nasal turbinates was thicker than the inner lining one. There were seromucous glands along the DNC, mucous glands in MNC. In the VNC, the glands were seromucous rostrally and abundant mucous caudally. These findings reflect the structural function relationship of camel turbinates that have a crucial role for the accommodation of inspired air during breathing in addition to olfaction.

Keywords: Turbinate bones; anatomy; histology; SEM; camel

INTRODUCTION

Camel (*Camelus dromedarius*) is a large herbivorous mammalian that lives in dry areas; especially in the Middle East and North Africa. They have great economic importance because they are considered a source of high-quality meat, dairy and leather products, they also have been involved in many racing sports (Badawy and Elmadawy, 2015).

The respiratory turbinates are complex bony plates covered with moist epithelium located in the nasal cavity (Van Valkenburgh et al., 2004) . In the skull, three distinct paired turbinates originating from different bones where, ethmoturbinates arise from the ethmoid bone; nasoturbinates from the nasal bone; and maxilloturbinates from the maxilla (Van Valkenburgh et al., 2004).

The nasal turbinates is essential for conditioning humidity, temperature, and olfaction of the inspired air (Kumar et al., 2000). The nasal turbinates of cattle was morphologically studied

(Adams, 1986), sheep (Barrios et al., 2014), goat (Kumar et al., 1993), dog (Kumar et al., 1994), cat (Van Valkenburgh et al., 2004), Pig (Sisson et al., 1975) and horse (Kumar et al., 2000).

The large complex concha, large sinuses and narrow nasal meatus of camel might be attributed to its living environment of frequent aridity and sand-storms (Bai et al., 2008). However, the nasal cavity of camels were previously studied (Abdel-Salam et al., 2014; Alsafy et al., 2014; Badawi and Fateh El-Bab, 1974; Cockrill, 1985; Metwally et al., 2019), there is no focused exploration of the camel nasal turbinates. This offers the important need to reveal a complete specification of the camel nasal turbinates during both prenatal as well as adult age. The complex organization of the anatomical camel nasal structures renders it difficult to be studied (Blanco et al., 2015). The sectional anatomy has been effectively used to evaluate the accurate topographical and morphological anatomy (Smallwood et al., 2002; De Zani et al., 2010).

The present study aims to focus on the morphological structures of the camel's turbinate bones through gross anatomy, Scanning Electron Microscope (SEM), and light Microscopy to understand the functional mechanisms that enable the camel to accommodate with the hot, dry and sandy inspired air during breathing in the desert nomads

MATERIALS AND METHODS

Collection of samples

The current study was carried out on amputated heads of fifteen camel fetuses and fifteen adult dromedary camels of both sexes. Specimens were collected immediately after slaughtering in a local abattoir (El-Basateen abattoir, Cairo, Egypt). The heads of camel fetuses were subjected to gross anatomical dissection while, the heads of adult camel were examined by gross dissection, light and scanning electron microscopy (SEM). All procedures for sampling were achieved according to the Guidelines for Animal Care in Kafrelsheikh University and university of Sadat city, Egypt. The used nomenclature in this research was adopted according to (Veterinaria, 2006) electronic edition whenever possible.

Gross anatomical studies:

The heads of camel fetuses:

The amputated heads of camel fetuses of either sexes of 37 to 84 cm crown vertebral rump (CVR) length were used. The CVR length was used to estimate gestational stage (El-Wishy, 1989). After evisceration, the fetuses were immediately collected and the crown to rump length was measured using a measuring band.

The fetal skulls were carefully dissected without boiling to elucidate the fine structures of the bone using a scalpel and toothed forceps. The general features of the camel skulls were examined in different views, i.e. lateral, dorsal, ventral, cranial and caudal. Some skulls were cut sagittally to improve examination. The examined specimens were photographed by a digital camera (*Sony 6 megapixels, Dsc-w50*).

The adult camel heads:

Two freshly amputated heads were boiled in water, cleaned, and dried to obtain the bony skull. Sagittal sections were made for a demonstration of osseous nasal turbinates. Other five heads were fixed in 10% formalin and 1% glycerin. Sagittal and transverse sections were made to examine the internal details of nasal turbinates throughout the nasal cavity.

Light microscopic studies:

Four heads were used for light microscopy. Samples from different nasal regions were fixed in Boun's solution for 24 hours. Then, the samples were dehydrated in increasing ethanol concentrations, immersed in xylene and embedded in paraffin wax. Sections of 5 µm thickness were made by rotatory microtome (LEICA RM 2035). Furtherly, the paraffin sections were stained by using Harris hematoxylin and Eosin (H&E), Periodic acid Schiff (PAS), Alcian blue and Crossman’s trichrome. Finally, the prepared sections were examined under a light microscope. The histological techniques and stains were adopted according to (Bancroft and Stevens, 1996).

The morphometric study was made by using ImageJ soft program. The stained sections of different nasal turbinates (DNC, dorsal nasal concha; MNC, middle nasal concha; VNC, ventral nasal concha; and EC, ethmoidal conchae) were used for this study. The results of the morphometric study were analyzed by paired *t*-test to compare between the outer covering and inner lining mucosa as well as underlying lamina propria submucosa in the outer and inner sides of each concha.

Scanning electron microscopy (SEM):

SEM was adopted according to Abumandour and Gewaily (2019). The collected specimens from four heads of adult camels were taken immediately after slaughtering and quickly cut into small blocks. These small blocks were fixed in 3% glutaraldehyde for 24 hours then dehydrated through a graded series of acetone. After dehydration, the blocks were transformed into the critical point drier, where a liquid Co2 gradually substitute the acetone within the tissue blocks according to the critical point drying method. The dried samples were mounted on metal stubs with conducting carbon paint and sputter-coated with gold by a sputtering device *(Teoljfc- 1100E)*. The specimens were examined with a scanning electron microscope *(Jeol jsm 5300)* at 25 KV, faculty of science, Alexandria University**.**

RESULTS

Prenatal morphology of camel nasal conchae

The nasal ethmoturbinates were found from the earliest stages of the development (37 CVRL camel fetuses). They were seven in number (I - VII) extended almost to the perpendicular plate of the ethmoid bone and the nasal septum (Fig. 1; C, D). The endoturbinates numerically named from the dorsal to the ventral direction.

Endoturbinate I (the dorsal nasal concha) occupied the dorsal part of the nasal cavity and extends from the cribriform plate of the ethmoidal bone to the rostral end of the nasal cavity (Fig. 1; C, F). It was smaller than the ventral nasal concha. The middle part was the widest, while both ends were tapered (Fig. 1; C, D, F). In cross-section, from the basal lamellae, the primary lamellae originated and curved ventrally to form the dorsal recess of the middle nasal meatus (Fig. 1; A). The caudal part of the concha was excavated to form the dorsal conchal sinus (Fig. 1; B, H). The medial surface of the concha was flat and separated from the nasal septum by the common nasal meatus, while the dorsal surface was convex and separated from the roof of the nasal cavity by the dorsal nasal meatus (Fig. 1; A, B).

Endoturbinate II (the medial middle nasal concha) was much smaller than the dorsal nasal concha and it was triangular in outline with its rostral end lied between the dorsal and ventral nasal conchae. It occupied the caudal part of the nasal cavity and divided the caudal part of the middle nasal meatus into dorsal and ventral parts (Fig. 1; D, F). It was excavated to form the medial middle conchal sinus (Fig. 1; E, H).

Endoturbinate III (the lateral middle nasal concha) resembled the medial middle nasal concha in the position and shape but was smaller in size. It located lateral to the middle one (Fig.1; B, E) and it also excavated to form lateral middle conchal sinus (Fig. 1; H). At 48.5 - 58 CVRL camel fetuses, from the ventral surface of the medial middle nasal concha there was a long extension which directs caudo-ventrally beneath the endoturbinates IV to VII and separated them from the ventral nasal concha (Fig. 1; C, D).

Endoturbinate IV to VII diminished in size respectively and lied ventral to the middle nasal conchae (Fig. 1; C, D). The intervening spaces among these endoturbinates were called the ethmoidal meatuses which continued with the dorsal and middle nasal meatuses (Fig. 1; D).

The ventral nasal concha was the largest and occupies majority of the nasal cavity. The ventral nasal concha was a part of the maxilla and was formed by the maxilloturbinate. The rostral end was pointed and bifid into small dorsal and ventral branches while the caudal end tapered beneath the endoturbinates IV to VII. The middle part was very wide, compressed medio-laterally and extended from the dorsad to ventrad occupying most of the internal surface of the maxilla (Fig. 1; D, F). The ventral nasal meatus separated the ventral border of the concha from the floor of the nasal cavity. It was larger than the dorsal and middle nasal meatuses (Fig. 1; D, F). In cross-section, at 37 cm CVRL camel fetus, the concha was attached to the maxilla by wide basal lamella which sloped ventromedial and branched into two plates rolled in opposite directions (Fig. 1; A).

The number and shape of rolls differed in the rostral and ventral convolutions and differed from rostral to caudal parts of the concha. At 37 CVRL camel fetuses, in the rostral part of the concha, the dorsal roll became one and a half turn and the ventral roll formed a ventral recess firstly then scrolled one turn (Fig. 1; A). At 37 and 84 CVRL camel fetuses the caudal part of the concha, the rolling process was reversed. The dorsal roll formed a ventral recess firstly then scrolled one and a half turn, while the ventral roll formed one and a half turn without a recess (Fig. 1; B, G). At 74 – 84 CVRL camel fetuses, in the caudal part of the concha, the basal lamella became twisted, resulting in a dorsal convolution took a medial position and a ventral convolution situated laterally (Fig. 1; E, H). By the subsequent stages of the development, the size of the concha and the number of the rolls increased respectively but without a change in the manner of the rolling process from rostral to the caudal direction (Fig. 1; G).

Postnatal morphology of camel nasal conchae

The gross morphology

Anatomically, the dorsal nasal concha, the medial middle nasal concha, and the ventral nasal concha enlarged obviously in size and protruded more rostrally with the ventral one was the largest. While, the other ethmoturbinates didn't growth over and located caudally only in the nasal fundus which attaches to cribriform plate of the ethmoid bone (Fig. 2; A, B).

The dorsal nasal concha (*Concha nasales dorsales*) was fixed to the ethmoidal crest of the nasal bone. It was represented rostrally by a basal lamella (Fig. 2; C) while the caudal two-thirds formed dorsal conchal sinus (Fig. 2; E). The dorsal conchal sinus joined the maxillary sinus through a lateral opening. The dorsal nasal concha rostrally terminated by the straight fold (Fig. 2; B). The middle nasal concha (*concha nasales medius*) was large and found in the caudal third of the nasal cavity proper between the dorsal and ventral nasal conchae (Fig.2; A, B). It was excavated and formed middle conchal sinus (Fig. 2; E).

The ventral nasal concha (*concha nasals ventrales*) was the longest and largest one of the nasal conchae. It appeared nearly S-shape along its length; its rostral part filled the rostral half of the nasal cavity proper (Fig. 2; A, B). It was formed of a basal lamella and two spiral lamellae; dorsal and ventral (Fig.2, C-E) that enclosed recess and bulla (Fig. 2; C, D). The caudal half of the ventral nasal concha was twisted to be nearly horizontal where the ventral spiral lamella was laterally situated to the dorsal one (Fig. 2; E). The basal lamella in the caudal half was large and the ventral spiral lamella was smaller than the dorsal one. The ventral nasal concha ended rostrally by a narrow fold from which the alar fold runs dorsolaterally towards the lateral nasal wing while the basal fold runs rostroventrally where it ended at the floor of the nasal vestibule (Fig. 2; B). The ethmoidal conchae (*the conchae ethmoidales*) were characterized grossly by a dark brown color which represented the olfactory region (Fig. 2; B).

Nasal meatuses:

The dorsal nasal meatus was a narrow passage extended from the dorsal nasal angle to the cribriform plate of the ethmoid bone. It was present between the roof of the nasal cavity and the dorsal nasal concha. Its average length was about 20cm while its average width was 0.5cm.

The middle nasal meatus (sinus meatus) extended from the level of the dorsal nasal angle to the ethmoidal concha. Its average width was about 1cm while its average length was the same as the dorsal nasal meatus. It was divided caudally (at the level of the 3rd cheek tooth) into dorsal and ventral meatuses due to presence of the middle nasal concha in the caudal third of the nasal cavity (Figs. 2, A, B).

The ventral nasal meatus was wider and longer than the other two meatuses (Figs. 2, A-D). The average width was 1.5cm while its average length was 22 cm (from the level of canine tooth to the level of the 5th cheek tooth). It was present between the ventral nasal concha and the floor of the nasal cavity. All previous meatuses opened freely into the common nasal meatus which located Para median between the nasal conchae laterally and the nasal septum medially and extended from the roof to the floor of the nasal cavity (Figs. 2, C).

Light (LM) and scanning electron microscopy (SEM)

As the nasal conchae were mainly occupying the nasal cavity proper (respiratory area) and extended rostrally into the nasal vestibule, so, the histological studies have clarified that their mucosal lining was mainly respiratory epithelium except for the rostral portion in the nasal vestibule and the caudal portion of the ethmoidal conchae.

A) The rostral part of nasal conchae:

The histological studies revealed that the epithelial lining of straight fold (of the dorsal nasal concha), the alar and basal fold (of the ventral nasal concha) were firstly keratinized in their rostral extension in the nasal vestibule, non-keratinized stratified squamous epithelium, passed through transition area of stratified cuboidal epithelium (Figs. 3; A, B and 4; A) then become of typical respiratory one (pseudostratified ciliated columnar epithelium with few goblet cells) with the beginning of the respiratory area (Figs.3, C, D).

The lamina propria submucosa of the previous three folds was dense irregular C.T. which was mainly formed of collagenous fibers. There were compound seromucous glands and their ducts were lined by simple columnar epithelium and changed to pseudostratified epithelium with goblet cells at the surface epithelium where these glands opened. Under these glands, there were many muscular arteries with well prominent lamina elastica interna in addition to the presence of venous plexuses (Figs. 3; A, B and 4; A, B). Hyaline cartilage (from the medial accessory cartilage) present in the basal and alar fold at their connection with the ventral concha. It was found in a deeper layer of submucosa, this cartilage was hyaline, covered by perichondrium and containing chondrocytes which presented in lacunae surrounded by a matrix (Figs. 3, B).

SEM of the vestibular region of camel nasal turbinates showed the presence of patches of poly angular microvillus cells. Cells with long microvilli may also present (Fig.7, B). At the mucous part of the nasal vestibule, the cells arranged giving wavy like appearance (Fig.7, C). More caudally and at the end of nasal vestibule, the squamous cells were non-keratinized and well-demarcated (Figs. 7, D). Openings of glands ducts were observed especially at the transition between mucous and cutaneous part of the nasal vestibule (Fig.7, A).

B) The middle part of the nasal conchae:

Generally, the lamina epithelialis of both dorsal and ventral nasal conchae decreased in its thickness towards the middle third of the nasal cavity. In both conchae, the outer covering epithelium of the nasal conchae was higher than the inner lining epithelium. The goblet cells increased gradually towards the middle portion till became the main cell type of the respiratory epithelium especially in the outer covering mucosa of the nasal conchae **(**Figs. 4, C, D).

There was bony lamella in the submucosa dividing the concha into two parts. The lamina propria submucosa of the outer side was thicker than that of the inner one. The main component of it was fibro elastic C.T. The venous plexus and small arterioles were abundant in the lamina propria of the outer covering epithelium than the inner one. The glands were mainly present in the side of the outer covering mucosa. In the dorsal nasal concha, they were simple seromucous glands, few and scattered under the lamina epithelialis, while in the ventral nasal conchae they were rarely found (Fig.3; C, D and 4, D).

SEM of respiratory region clarified ciliated and goblet cells with a dominance of ciliated cells. There were openings of glands ducts leaving prominent channels due to passage of their secretion on the epithelial surface (Fig.8; A). The goblet cells appeared as unicellular mucous glands found between the ciliated columnar cells and increased in number towards the caudal portion of the respiratory region (Figs. 8; B, C). The ciliated cells possessed numerous cilia of uniform thickness. In between the ciliated cells, dom-shaped goblet cells were present (Fig.8; D).

C) The caudal portion of the nasal conchae:

This part of the nasal cavity included the caudal third of both dorsal and ventral nasal conchae, the middle nasal concha and the ethmoidal conchae. In the dorsal nasal concha, the number of goblet cells increased and the number of seromucous glands decreased (Figs.3; E, F). The ventral nasal concha was relatively similar to the middle portion but, the glands were prominent, numerous and mainly mucous secreting showing positive reaction with Alcian blue and PAS stains (Figs.5; A, B). The middle nasal concha was lined by thick pseudostratified ciliated columnar epithelium with many goblet cells. The lamina propria submucosa was dense irregular C.T containing abundant mucous glands in the upper layer and venous plexuses in the underlying part (Figs.5; C, D); this was similar to the ventral nasal concha in this region.

Olfactory region (Regio Olfactoria):

The olfactory area of the nasal turbinates was characterized grossly by a dark brownish coloration restricted to the ethmoidal conchae. The histological study revealed that the olfactory epithelium was comparatively thicker than that of the respiratory region and comprised three cell types; bipolar (olfactory) cells, supporting (sustentacular) cells and basal cells (Fig.6; A, B, D). The basal cells were small polyhedral cells rested on a prominent basal lamina and not reach the surface. Their cytoplasm was basophilic and their nuclei were large, oval and centrally located showing signs of mitotic activity. The supporting cells were elongated cells extended from the basal lamina to the surface. The basal portion of the cells was narrow and not clear due to crowded olfactory cells while the apical portion was wide and brushed. Their nuclei were large, darkly basophilic and occupied the upper portion of the epithelium. The lamina propria submucosa consisted of loose C.T of collagenous and delicate elastic fibers (Fig.6; D). Many bundles of unmyelinated nerve fibers (olfactory nerve) were also observed as well as small blood vessels in the deepest layer of the lamina propria. The inner lining epithelium was comparatively very thin and very rich in goblet cells. Many C.T fibers were observed in the submucosa with no evidence of any glands (Figs.6; C).

SEM of the olfactory area revealed protuberant olfactory vesicles from which olfactory cilia radiated in various directions. Besides the olfactory cells, there were supporting cells which had no cilia (Fig.9; A, B). Very small sized projections were observed at the surface of olfactory cells on both apical and lateral surfaces of olfactory cells (Fig.9; B, C). By high magnification, there was bleb like apical protrusions in the ciliated surface of olfactory vesicles (Fig.9; D). The gross anatomy, lining epithelium and types of glands along the different parts of nasal turbinates of adult camel were summarized in Table 1 while; the results of the morphometric study were shown in Table 2.

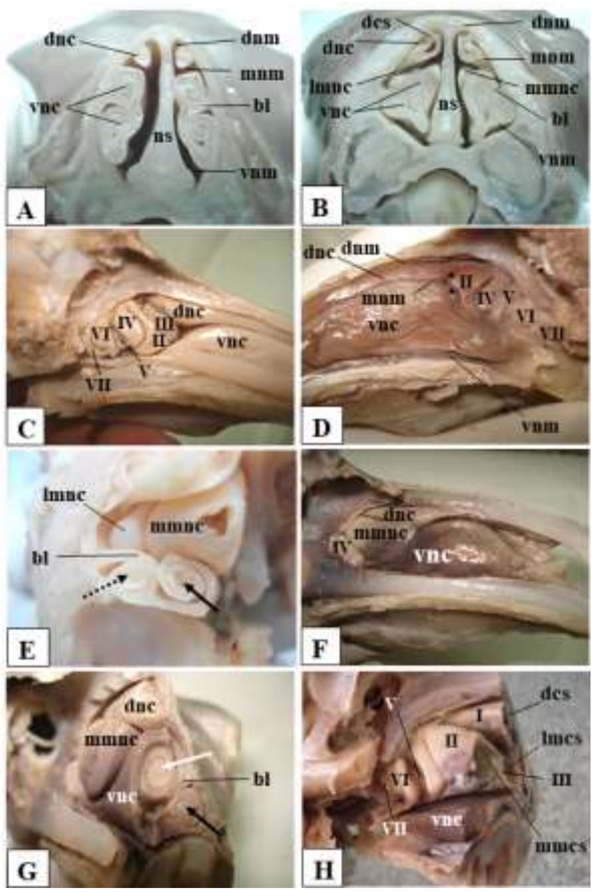

Figure 1: A; Cross section at the level of the first molar tooth in the nasal cavity of the skull of a fetal specimen with 37 cm CVR length. B; Cross section at the level of the third molar tooth in the nasal cavity of the skull of a fetal specimen with 37 cm CVR length. C; Lateral view of the skull of a fetal specimen with 48.5 cm CVR length. D; Lateral view of the skull of a fetal specimen with 58 cm CVR length. E; Cross-section at the level of the last molar tooth in the nasal cavity of the skull of a fetal specimen with 74 cm CVR length shows that the basal lamella (bl) gets so twisted that the dorsal convolution becomes medial (black arrow) and the ventral convolution becomes lateral (dotted black arrow) in positions. F; Lateral view of the skull of a fetal specimen with 84 cm CVR length. G; Cross-section at the level of the third molar tooth in the nasal cavity of the skull of a fetal specimen with 84 cm CVR length shows that the dorsal roll forms a ventral recess firstly then scrolls one and a half turn (white arrow) while the ventral roll forms one and a half turn without recess (black arrow). H; Lateral view at the caudal part of the nasal cavity of the skull of a fetal specimen with 84 cm CVR length. dnc; dorsal nasal concha, vnc; ventral nasal conchae, basal lamellae (bl). ns; nasal septum, dnm; dorsal nasal meatus, mnm; middle nasal meatus, vnm; ventral nasal meatus, dcs; dorsal conchal sinus, mmnc; medial middle nasal concha, lmnc; lateral middle nasal concha, dcs; dorsal conchal sinus, mmcs; medial middle conchal sinus, lmcs; lateral middle conchal sinus, II; medial middle nasal concha, III; lateral middle nasal concha, endoturbinate IV, endoturbinate V, endoturbinate VI, endoturbinate VII. The middle nasal meatus is divided caudally dorsal and ventral to the medial middle nasal concha into dorsal and ventral parts (black stars).

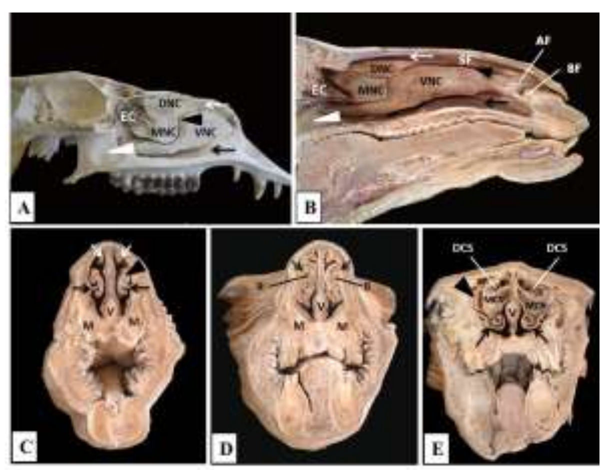

Figure 2: photograph of adult dromedary camel head. A; a sagittal section of the skull of the camel showing nasal turbinates (DNC, MNC, VNC, and EC). B; a sagittal section of the camel head showing nasal conchae and their folds; straight

fold (SF), alar fold (AF) and basal fold (BF), dorsal (white arrow), ventral (black arrow) and middle (black arrowhead) nasal meatuses, and choana (white arrowhead). C represents cross-section at 1st cheek tooth. Only the basal lamella of DNC (white arrow) and VNC (black arrow) could be found. D represents cross-sections at 2nd cheek tooth. The spiral lamellae (black arrow) of VNC form recess (R) and bulla (B). E represents cross-sections at 4th cheek tooth. The DNC form dorsal conchal sinus (DCS), the MNC forms middle conchal sinus (MCS) and the VNC represented by two spiral lamellae; dorsal (black arrowhead) and ventral (black arrow). V refers to vomer and M refers to maxilla.

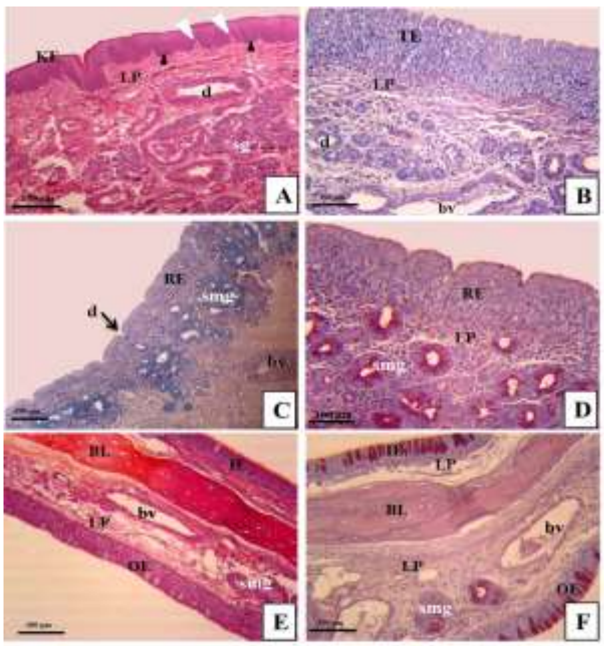

Figure.3: Histomicrograph of the DNC of the dromedary camel. A, B represent the straight fold. A show keratinized epithelium (KE) with connective tissue papillae (white arrowhead) and epithelial pegs (black arrowhead), lamina propria (LP) and serous glands (sg) with their ducts (d). B shows transition epithelium (TE) of stratified cuboidal cells under it; there are lamina propria (LP) and serous glands (sg). C, D represent the middle part of DNC which contains respiratory epithelium (RE; pseudostratified ciliated columnar), lamina propria (LP), seromucous gland (smg) with their ducts (d) and blood vessels (bv). E, F represent the caudal third of DNC. OE; outer epithelium, IE; inner epithelial lining, LP; lamina Propria, bv; blood vessels, BL; bony lamella and smg; seromucous glands. Stain H&E (A, E), Alcian blue (C) and PAS (B, D, F). Bar= 100 µm except C (200 µm).

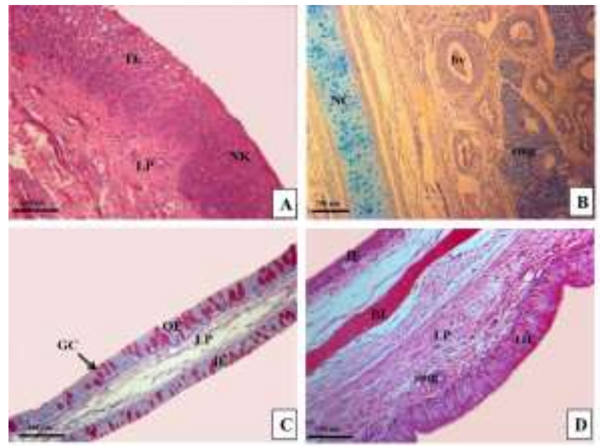

Figure 4: Histomicrograph of the rostral two-thirds of VNC of the dromedary camel. A show transition zone in the basal fold which graduates from non-keratinized (NK) stratified squamous epithelium to stratified cuboidal epithelium (TE). B shows a part of nasal cartilage (NC) supporting the alar fold in addition to seromucous glands (smg) and blood vessels (bv). C represents the lining epithelium of VNC at the beginning of the respiratory area with the absence of the turbinate bone. The epithelium in both sides is nearly similar and rich in goblet cells (GC). D represents the whole thickness of VNC in its middle third. It shows outer covering epithelium (OE) lamina propria (LP) with very little seromucous gland (smg) in addition to inner lining epithelium (IE) and bony lamella (BL) between both sides. Stain H&E (A, D), Alcian blue (B) and PAS (C). Bar= 200 µm in B and 100 µm in A, C, D.

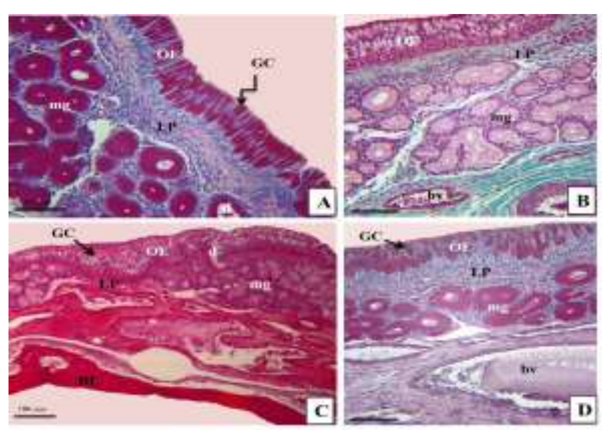

Figure.5: Histomicrograph of the caudal third of VNC (A, B) and the MNC (C, D) of the dromedary camel. A, B show the outer epithelium (OE) with abundant PAS-positive goblet cells (GC), Lamina propria (LP) with PAS-positive mucous glands (mg), in addition to blood vessels and connective tissue fibers. B, C show the outer epithelium (OE) with many PAS-positive goblet cells (GC), Lamina propria (LP), PAS-positive mucous glands (mg), in addition to blood vessels and the bony lamella of the MNC. Stain PAS (A, D), Trichrome (B) and H&E (C). Bar= 200 µm in C and 100 µm in A, B, D.

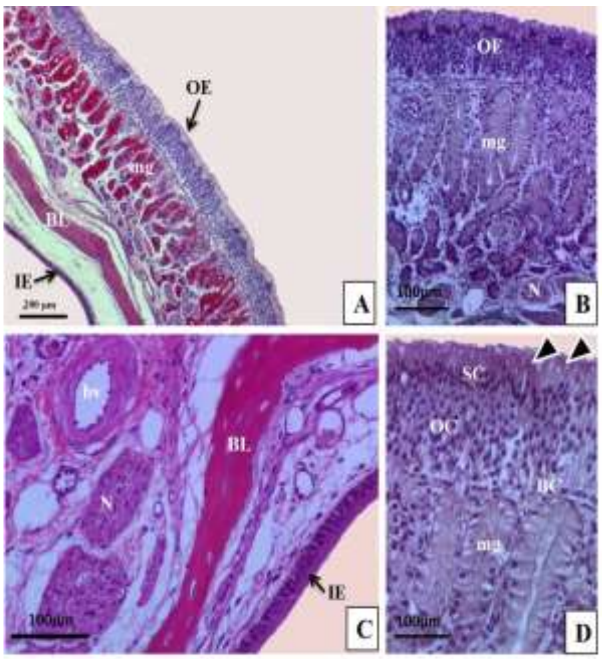

Figure 6: Histomicrograph of the ethmoidal conchae of the camel. A demonstrates the outer olfactory epithelial lining (OE), inner epithelial lining represented by simple cuboidal epithelium with goblet cells (IE), PAS-positive mucous glands and the bony lamella of ethmoidal conchae (BL). B, represent the outer olfactory epithelium (OE), mucous glands (mg) arranged in a linear manner and olfactory nerve fibers (N). C shows the inner epithelial lining, the bony lamella (BL), nerve fibers (N) as well as blood vessels (bv). D shows the three cell types of the olfactory epithelium; basal cell (BC), supporting cells (SC) and olfactory cells (OC) with olfactory hair-like cilia (arrowhead) giving apical brush appearance. The mucous glands (mg) arranged in a striated manner under the epithelium. Stain; PAS in A and H&E in B, C, D. Bar= 200 µm in A and 100 µm in B, C, D.

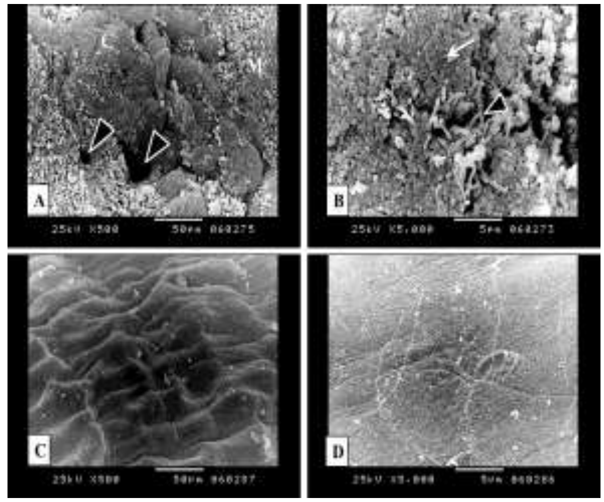

Figure 7: Scanning electron micrograph of the vestibular region of the camel nasal turbinates. A, B present in the straight fold; A reveals the transition zone between cutaneous (C) and mucous (M) part as well as glandular duct openings (arrowhead). B shows poly angular microvillar cells as well as ciliated microvillar cells. C in the alar fold shows the wavy-like arrangement of epithelial cells. D in the basal fold shows demarcated squamous cells. Bar= 50 µm (A, C) and 5 µm (B, D).

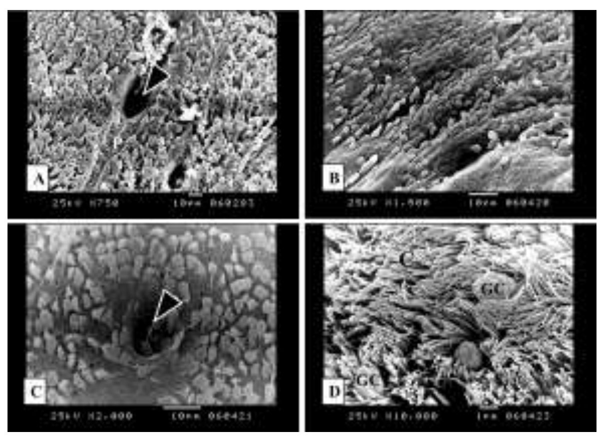

Figure 8: Scanning electron micrograph of Respiratory region of the camel nasal turbinates. A; in the middle part of DNC, shows ciliated respiratory epithelium with openings of glands (arrowhead) which convey their secretion and make a passage (P) on the epithelial surface. B, C; in the middle part of VNC, show respiratory epithelium with many goblet cells and opening of the glandular duct (arrowhead). D, in the caudal part of DNC; shows respiratory epithelium with

cilia (C) and goblet cells (GC). Bar= 10 µm (A, B, C) and 1 µm (D).

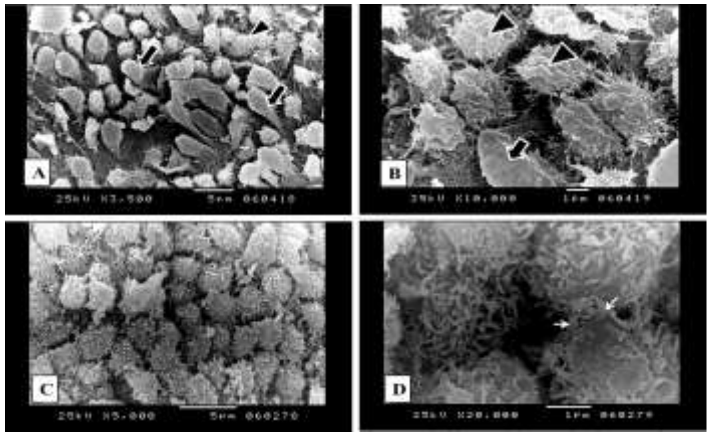

Figure 9: Scanning electron micrograph of the olfactory region of camel nasal ethmoturbinates. A, B show supporting cells (arrow) and olfactory vesicles with hairy like projections (arrowhead). C, D show the olfactory vesicles with bleb-like olfactory cilia. Bar = 5 µm (A, C) and 1 µm (B, D).

Table 1: Summarizes the gross anatomy, lining epithelium and types of glands along the different parts of nasal turbinates of adult camel. DNC; Dorsal Nasal Concha, MNC; Middle Nasal Concha, VNC; Ventral Nasal Concha, EC; Ethmoidal Conchae, (-) absence of referred concha in that region.

	DNC	MNC	VNC	EC
Rostral				
Grossly	Basal lamella	–	Basal lamella	–
Type of epithelium	Stratified squamous, then, the respiratory epithelium	–	Stratified squamous, then, respiratory epithelium with few goblet cells	
Glands	Mainly serous glands	–	seromucous glands	
Middle				
Grossly	Dorsal conchal sinus	–	A basal lamella and two spiral lamellae	–
Type of epithelium	Respiratory epithelium	–	Respiratory epithelium with goblet cells	
Glands	Seromucous glands	–	Seromucous glands rarely found	
Caudal				
Grossly	Dorsal conchal sinus	Middle conchal sinus	A basal lamella and two spiral lamellae with recess and bulla	Dark brown small conchae in the nasal fundus
Type of epithelium	Respiratory epithelium	Respiratory epithelium with many goblet cells	Respiratory epithelium	Olfactory epithelium
Glands	Seromucous glands	Abundant mucous glands	Mucous glands	Mucous glands

Table 2: Morphometry of the nasal turbinates of adult dromedary camel DNC; Dorsal Nasal Concha, MNC; Middle Nasal Concha, VNC; Ventral Nasal Concha, EC; Ethmoidal Concha, Ep: Epithelium, LP; Lamina Propria submucosa, Values were presented as mean ± SEM. Values bearing different letters were significantly different (paired t-test, P ＜ 0.05).

	Epithelium thickness (μm)		Propria submucosa thickness (μm)	
	Outer	Inner	Outer	Inner
DNC	53.86± 1.412[a]	44.22± 1.453[a]	166.1± 5.511[a]	77.06± 6.081 [ab]
MNC	128.3± 11.42[a]	81.49± 3.326[ab]	710.2± 42.66[a]	219.7± 18.45 [ab]
VNC	72.64± 3.150[a]	29.24± 0.9663[ab]	193.7± 6.050[a]	85.94± 2.751 [ab]
EC	114.6± 4.179[a]	28.06± 2.654[ab]	408.7± 9.048[a]	102.8± 2.840 [ab]

DISCUSSION

The camel endoturbinates were attached to the dorsal and lateral wall of the cribriform plate of the ethmoid bone. They protruded into the nasal cavity and their numbers vary on each side in the different species; four in the dog, four in the ruminant, six in the horse and seven in the pig (Konig et al., 2004). The present thesis revealed that the number of the endoturbinates of the camel was seven with the third being well developed and protrudes into the nasal cavity lateral to the middle nasal concha. They could be described as ethmoturbinate I, II, III, IV, V, VI, and VII.

The endoturbinate I formed the dorsal nasal concha and the endoturbinate II formed the middle nasal concha. While the dorsal and middle nasal conchae were formed by the ethmoturbinates, the ventral nasal concha was a part of the maxilla and it formed by the maxilloturbinate. The following ethmoturbinates diminished gradually in size in all species except for the dog in which the second to fourth ethmoturbinates were well developed with the third being longer than the fourth one (Konig et al., 2004).

The present work on the ethmoturbinates of the camel fetus revealed that the middle nasal conchae were divided into the medial middle nasal concha which is larger and the lateral middle nasal concha which is smaller than the medial one. The conchal sinuses formed by both conchae respectively take the same terms, medial middle conchal sinus and lateral middle conchal sinus.

The size and shape of ethmoturbinates are varied from one individual to another, (Yılmaz et al., 2010). The general organization and topography of the ethmoturbinates is determined by the initial appearance and further growth of endoturbinates which define the division of the cavity into upper, middle and lower regions (Hegner, 1962; Menke, 2003).

The morphological properties of the nasal conchae may relate to the adaptability olfactory and respiratory function during living in desert conditions (Jianling, 1993; Bai et al., 2008). The nasal concha in camel has special properties that differ from that in the horse, buffalo, and cattle, and these properties may relate to reducing inhaled dust and sand (Morrow et al., 2000; Bai et al., 2008; Alsafy et al., 2014). The conchal arrangement has special properties in camels, where, they were condensed only in the caudal two thirds. Only the straight, alar and basal folds were found rostrally. On the other hand, the nasal conchae of ruminants and equine were similar and extended through the whole length of the nasal cavity (Metwally et al., 2019).

(Blanco et al., 2015) reported that the nasal conchae are mainly found in the middle portion of the nasal cavity, while the ethmoidal conchae are situated caudally.

In the cross-sectional anatomy of this work, the dorsal nasal concha was simple as other endoturbinates arising from the ethmoidal system of conchae and contained conchal sinus. This agrees with that reported by (Alsafy et al., 2014; Metwally et al., 2019). In contrast, the ventral nasal concha was complex and has different shape according to species (Schaller and Constantinescu, 2007). The ventral nasal concha was divided into dorsal and ventral parts which give S shape of concha and twisting allowing condensation of nasal conchae in the caudal two thirds in agreement with (Metwally et al., 2019) and did not contain a sinus but it has two spiral lamellae which form recess and bulla like that reported by (Smuts and Bezuidenhout, 1987; Alsafy et al., 2014). The caudal half of the dorsal nasal concha contains a nasal conchal sinus, which communicates with the middle meatus as demonstrated by(Smuts and Bezuidenhout, 1987; Alsafy et al., 2014).

The dorsal nasal concha extends rostrally by a straight fold while the ventral nasal concha extended by alar fold rostro-dorsally and basal fold rostro-ventrally. The straight, alar and basal folds were slender in the camel if compared with those of the horse (Ahmed et al., 1985). The straight fold camels, was straight as its name while in donkeys (Hamoda, 2000) and horse (Getty and Sisson, 1975), it was represented by two rounded ridges, supported by cartilages then, rejoined again as one straight fold. In camels, there is no cartilaginous support but in buffalo; it contained a cartilaginous prolongation (Smuts and Bezuidenhout, 1987).

According to our study, the ventral nasal concha was the longest in camel like that mentioned by (Badawi and Fateh El-Bab, 1974; Metwally et al., 2019). Conversely, the dorsal nasal conchae were shorter and smaller than the ventral one. In the ruminants and equine, the dorsal nasal concha was the longest one based on the extension of turbinate bone without the mucosal fold (Nickel et al., 1979; Kumar et al., 2000; Metwally et al., 2019). The alar and basal folds were raised from a common extension (Metwally et al., 2019). The ventral conchal sinus which formed caudally by the spiral lamellae in the ox (Nickel et al., 1979) was not formed in the camel.

The middle nasal concha lies caudal to the ventral nasal concha, communicates with the fundus nasi (Blanco et al., 2015). It was large in the camel and divides the middle nasal meatus into dorsal and ventral channels caudally (Fathel-Bab, 1970; Badawi and Fateh El-Bab, 1974; Moussa and Mokhtar, 2005). In agreement with (Badawi and Fateh El-Bab, 1974), the middle nasal concha is excavated to enclose the large middle conchal sinus in agreement with (Alsafy et al., 2014; Metwally et al., 2019). On the other hand, the dorsal and ventral spiral lamellae of this concha that mentioned by (Moussa and Mokhtar, 2005) were not observed in our study. (Abd-El-Aziz, 1983) stated in the buffalo that the middle nasal concha is excavated to form the middle conchal sinus while in ox this sinus was formed by the dorsal spiral lamella (Nickel et al., 1979). The middle nasal concha in the horse was small and encloses the middle conchal sinus (Sisson et al., 1975).

In the current study, the ethmoidal conchae rather than DNC and MNC were 5 in number but (Fathel-Bab, 1970; Moussa and Mokhtar, 2005) stated that they were 5 – 6 in number. A larger number of ethmoidal conchae (20 – 30) were recorded in ox and horse (Nickel et al., 1979). The ethmoidal conchae were occupied the most caudal part of the nasal cavity and characterized by dark brownish color referring to the olfactory area.

The nasal meatuses of camel were narrow spaces between the nasal conchae. The ventral meatus was wider than that of the horse while, the dorsal and middle meatus was narrower and this can also additionally relate to the adaptability to the barren region environment (Clifford and Witmer, 2004; Alsafy et al., 2014). Moreover, the middle nasal meatus was divided caudally by the middle nasal concha.

The lining epithelium of the nasal turbinates in the camel was gradually changed in a rostrocaudal direction from keratinized stratified squamous epithelium in the vestibule to ciliated pseudostratified columnar epithelium in the respiratory region until it terminates by the olfactory epithelium in the olfactory region; this gradation was compatible with that found in the other mammals (Reznik, 2017). There was a transition zone of stratified cuboidal epithelium between lining epithelium in the vestibular and respiratory region like that reported by (Abdel-Salam et al., 2014). The epithelium in the respiratory region of the nasal cavity of the camel showed massive ciliated surface (Zayed, 2004).

The keratinized epithelium lining the straight, alar and basal folds was necessary to protect the underlying tissues against tear and fluid evaporation. Its cutaneous epithelium in the rostral part of the nasal conchae was graded caudally into a respiratory mucous membrane, through a transitional zone formed of a stratified cuboidal non-ciliated epithelium (Abdel-Salam et al., 2014). It could be suggested that this transition epithelium, with the sub-epithelial glands, might sustain both protection and air correction (Adams, 1990). The sub-epithelial mucous glands noted in the transition zone, collectively with these considered in the nasal vestibule, have additionally been located in rat (Phipps, 1981) and in the horse (PIRIE et al., 1990). Caudal to the transitional zone, the nasal cavity was lined by a typical respiratory epithelium formed of pseudostratified ciliated columnar epithelium.

The respiratory region caudal to the vestibule was mainly lined by pseudostratified ciliated columnar epithelium with flask-shaped goblet cells. The subepithelial mucous glands showed both acidic and neutral mucosubstances content in agreement with (Abdel-Salam et al., 2014). The morphology of the goblet cell in the camel was similar to that of previously studied goblet cell in the nasal epithelium of the dog and human (OKANO and SUGAWA, 1965; Thaete et al., 1981).

According to our study, SEM showed microvillar cells in the most rostral part and flask-shaped goblet cells in the respiratory region. (Abdel-Salam et al., 2014) supposed that the microvillar cells are premature goblet cells with apical short microvilli that might play a role in water absorption leading to rupture of the goblet cells and the release of their mucous content.

These sub-epithelial glands are associated with the abundant secretions produced by the nasal epithelium in the camel nasal cavity in agreement (Kahwa and Purton, 1996) in goat. This secretion is essential for maintaining the required humidity and may represent as a source for abundant viscous secretion released in allergic inflammatory conditions (Phipps, 1981). (Abdel-Salam et al., 2014) reported that the hygroscopic mucus lining the nasal and respiratory passages of the camel dries out during inspiration and recovers moisture during expiration from expired air, thus considerably decreasing insensible losses of water. the secretory product of the goblet cells of the airway surface epithelium as well as the submucosal glands contain a viscoelastic gel containing water, carbohydrates, lipids, and proteins. These contents are highly important for the maintenance of airway integrity and protection of the epithelium from foreign material and fluid loss (Rubin, 2002).

The olfactory area in the camel turbinates was a relatively small area when grossly compared with the respiratory region. A small olfactory regions were also recorded in sheep (Barrios et al., 2014) while carnivora and rodents had large areas for olfaction (Reznik, 1990). The olfactory areas of camel are not covered by ciliated cells and are devoid of goblet cells like other mammals and man (Reznik and Jensen, 1979).

The general characteristics of the olfactory sensory epithelium of adult camel agree with other studies (Kratzing, 1970; Kolb, 1979; Kavoi et al., 2010; Barrios et al., 2014). The olfactory region of camel turbinates was characterized grossly by dark brownish coloration and was comparatively thicker than that of the respiratory region. It comprised three cell types: olfactory, supporting and basal cells (Kumar et al., 2000; Abdel-Salam et al., 2014). In most species, most of the olfactory sensory epithelium occupies a single continuous area of the nasal cavity, the main olfactory epithelium (Menco and Morrison, 2003). In some species like mice, however, Olfactory Sensory Neurons (OSNs) are also found in other regions of the nasal cavity (Barrios et al., 2014).

(Kolb, 1979) reported that it extends to the most anterior part of the dorsal and ventral conchae. The olfactory sensory epithelium is composed of basal cells, neurons, and sustentacular cells organized in strata (Barrios et al., 2014).

It is worthily to mention that the outer mucosal lining, as well as the lamina propria submucosa, is thicker than the inner side that is also devoid of any glandular tissue at the level of all types of nasal turbinates of the camel. This is similar to that previously demonstrated in horses (Kumar et al., 2000). This finding may be due to direct contact of the outer surface of nasal turbinates with the passing air through the nasal cavity to enable it to function for the accommodation of the inspired air.

CONCLUSION

In conclusion, the characteristic features related to the shape of the camel nasal turbinates, the narrow nasal meatuses, the graduation of mucosal lining and the secretion of goblet cells rather than subepithelial glands enable the camel to sustain the hard living conditions in the desert nomads.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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REFERENCES

Abd-El-Aziz, S, 1983. Some anatomical studies on the nasal cavity of the buffalo in Egypt.

Abdel-Salam, LR, Moukhtar, H, Abdel-Raouf, A, Amer, A, 2014. Histological, histochemical and scanning electron microscopical study of nasal cavity epithelium of the dromedary camel (Camelus dromedarius). Journal of Basic Medicine Allied Science 2, 1-14.

Abumandour, MM, Gewaily, MS, 2019. Gross morphological and ultrastructural characterization of the oropharyngeal cavity of the Eurasian hoopoe captured from Egypt. Anatomical Science International, 94 (2), 172-179. doi:0.1007/s12565-018-0463-9

Adams, D, 1990. Epithelium lining the rostral portion of the porcine nasal mucosa. Research in veterinary science 49(1), 61-65.

Adams, DR, 1986. Transitional epithelial zone of the bovine nasal mucosa. American journal of anatomy 176 (2), 159-170.

Ahmed, A, Shokry, M, El-Keiey, M, 1985. Contribution to the paranasal sinuses of the one humped camel (Camelus dromedarius). Anatomia, histologia, embryologia 14 (3), 221-225.

Alsafy, MA, El-gendy, SA, Abumandour, MM, 2014. Computed tomography and gross anatomical studies on the head of one-humped camel (Camelus dromedarius). The Anatomical Record 297 (4), 630-642.

Badawi, H, Fateh El-Bab, M., 1974. Anatomical and histological studies on the nasal cavity of the camel, Camelus dromedaries. Assuit Vet. Med. J 1, 1-14.

Badawy, AM, Elmadawy, RS, 2015. Computed Tomographic Features of the Camel Nasal Myiasis. Journal of Advanced Veterinary Research 5(2), 47-52.

Bai, Z, Wang, H, Chen, J, Yuan, G, He, J, Wang, J, 2008. The computed tomography and gross anatomies of nasal cavity and sinuses in the Bactrian camel (Camelus bactrianus). Sciencepaper Online, 1-9.

Bancroft, J, Stevens, A, 1996. Theories and practice of histological techniques. Churchill Livingstone, New York, London, Tokyo.

Barrios, AW, Sanchez Quinteiro, P., Salazar, I., 2014. The nasal cavity of the sheep and its olfactory sensory epithelium. Microscopy research and technique 77 (12), 1052-1059.

Blanco, D, Rivero, M, Vázquez, J, Arencibia, A, 2015. Sectional Anatomic and Computed Tomography Features of the Nasal and Oral Cavities of the One-humped Camel (Camelus Dromedarius). Anatomia, histologia, embryologia 44(1), 50-58.

Clifford, AB, Witmer, L.M., 2004. Case studies in novel narial anatomy: 2. The enigmatic nose of moose (Artiodactyla: Cervidae: Alces alces). Journal of Zoology 262 (4), 339-360.

Cockrill, WR, 1985. The camelid: an all-purpose animal. Vol. 2, Bibliography. Nordiska Afrikainstitutet.

De Zani, D, Borgonovo, S, Biggi, M, Vignati, S, Scandella, M., Lazzaretti, S, Modina, S, Zani, D, 2010. Topographic comparative study of paranasal sinuses in adult horses by computed tomography, sinuscopy, and sectional anatomy. Veterinary research communications 34 (1), 13-16.

El-Wishy, A, 1989. Genital Abnormalities of the Female Dromedary (Camelus dromedurius). An Abattoir Survey. Reproduction in Domestic Animals 24 (2), 84-87.

Fathel-Bab, M, 1970. Anatomy and histology of the respiratory system of the camel. MVSc Thesis, Assiut Fac. Vet. Med., Assuit University, Egypt.

Getty, R, Sisson, S, 1975. Sisson and Grossman's the Anatomy of the Domestic Animals.

Hamoda, H, 2000. Some anatomical studies on the nasal cavity of the donkey. MV Sc. Thesis, Kafr El-Sheikh Faculty of Veterinary Medicine, Tanta University, Egypt.

Hegner, D., 1962. Zur Morphologie der Ethmoturbinalia von Ovis aries und Capra hircus. Berl. Münch. Tierärztl. Wschr 75, 445-447.

Jianling, W, 1993. Dissection of skull of bactrian camel (external shape). Journal of Gansu Agricultural University.

Kahwa, C, Purton, M, 1996. Histological and histochemical study of epithelial lining of the respiratory tract in adult goats. Small ruminant research 20 (2), 181-186.

Kavoi, B, Makanya, A, Hassanali, J, Carlsson, HE, Kiama, S., 2010. Comparative functional structure of the olfactory mucosa in the domestic dog and sheep. Annals of Anatomy-Anatomischer Anzeiger 192 (5), 329-337.

Kolb, Av, 1979. Lichtmikroskopische Untersuchungen an der Riechschleimhaut des Hausschafes (Ovis aries L.). Anat. Anz 146, 444-455.

Konig, H, Liebich, H, Maierl, J, 2004. Text Book and Color Atlas of Veterinary Anatomy of Domestic Mammals. and.

Kratzing, JE, 1970. The olfactory mucosa of the sheep. Australian Journal of Biological Sciences 23 (2), 447-458.

Kumar, P., Kumar, S., Singh, Y., 1993.

Histological studies on the nasal ethmoturbinates of goats. Small Ruminant Research 11(1), 85-92.
Kumar, P, Kumar, S, Singh, Y, 1994. Histology of nasal turbinates in dog. Indian Journal of Animal Sciences (India).
Kumar, P, Timoney, J, Southgate, H, Sheoran, A, 2000. Light and scanning electron microscopic studies of the nasal turbinates of the horse. Anatomia, histologia, embryologia 29 (2), 103-109.
Menco, B, Morrison, E.E., 2003. Morphology of the mammalian olfactory epithelium: form, fine structure, function, and pathology. NEUROLOGICAL DISEASE AND THERAPY 57, 17-50.
Menke, C, 2003. Morphologie und topographische Anatomie der Nase, der Nasenhöhle sowie der Nasennebenhöhlen und assoziierten Strukturen beim Europäischen Mufflon (Ovis gmelini musimon PALLAS 1811). Verlag nicht ermittelbar.
Metwally, MA, Hussieni, HB, Kassab, AA, Eshrah, EA, 2019. Comparative Anatomy of the Nasal Cavity in Buffaloes, Camels and Donkeys. Journal of Advanced Veterinary Research 9 (2), 69-75.
Morrow, KL, Park, RD, Spurgeon, TL, Stashak, TS, Arceneaux, B, 2000. Computed tomographic imaging of the equine head. Veterinary Radiology & Ultrasound 41(6), 491-497.
Moussa, E, Mokhtar, A, 2005. Anatomical Features and Histology of the Nasal Cavity of One Humped Camel (Camelus dromedarius). Anatomia, Histologia, Embryologia 34, 34-34.
Nickel, R, Schummer, A, Seiferle, E, Sack, WO, 1979. The viscera of the domestic mammals. Springer.
OKANO, M, SUGAWA, Y, 1965. Ultrastructure of the respiratory mucous epithelium of the canine nasal cavity. Archivum histologicum japonicum 26(1), 1-21.
Phipps, R, 1981. The airway mucociliary system. International review of physiology 23, 213-260.
PIRIE, M, Pirie, H, CRANSTON, S, Wright, N, 1990. An ultrastructural study of the equine lower respiratory tract. Equine veterinary journal 22 (5), 338-342.
Reznik, G, 2017. Comparative anatomy and histomorphology of the nasal and paranasal cavities in rodents, Nasal Tumors in Animals and Man Vol. I. CRC Press, pp. 35-44.
Reznik, G, Jensen, K, 1979. Anatomy of the nasal cavity of the European hamster (Cricetus cricetus). Zeitschrift fur Versuchstierkunde 21(6), 321-340.
Reznik, GK, 1990. Comparative anatomy, physiology, and function of the upper respiratory tract. Environmental health perspectives 85, 171-176.
Rubin, BK, 2002. Physiology of airway mucus clearance. Respiratory care 47(7), 761-768.
Schaller, O, Constantinescu, GM, 2007. Illustrated veterinary anatomical nomenclature. Georg Thieme Verlag.
Sisson, S, Grossman, JD, Getty, R, 1975. Sisson and Grossman's the Anatomy of the Domestic Animals. Saunders.
Smallwood, JE, Wood, BC, Eric Taylor, W, Tate Jr, LP, 2002. Anatomic reference for computed tomography of the head of the foal. Veterinary Radiology & Ultrasound 43 (2), 99-117.
Smuts, MMS, Bezuidenhout, AJ, 1987. Anatomy of the dromedary. Oxford University Press.
Thaete, L, Spicer, S, Spock, A, 1981. Histology, ultrastructure, and carbohydrate cytochemistry of surface and glandular epithelium of human nasal mucosa. American Journal of Anatomy 162 (3), 243-263.
Van Valkenburgh, B, Theodor, J, Friscia, A, Pollack, A, Rowe, T, 2004. Respiratory turbinates of canids and felids: a quantitative comparison. Journal of Zoology 264 (3), 281-293.
Veterinaria, NA, 2006. Electronic edition. Published by the international committees on veterinary gross anatomical nomenclature under the financial responsibility of the world association of veterinary anatomists. Zurich and Ithaca, New york.
Yılmaz, NA, Cicekcibasi, AE, Emlik, D, Yılmaz, MT, Keles, B, Salbacak, A, 2010. Morphometric analyses of the development of nasal cavity in human fetuses: An anatomical and radiological study. International journal of pediatric otorhinolaryngology 74(7), 796-802
Zayed, AE Anatomical, scanning electron and light microscopical studies on the prenatal development of the nasal conchae of the one-humped camel (Camelus dromedarus). Assiut Vet. Med. J., 2004; 50 (100).