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Morphometrical, radiological and histochemical study of the internal olfactory bones in camels (*Camelus dromedarius*)

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Abstract

The current research aimed to expand on the morphometry, radiology and histochemistry of the internal olfactory bones in 12 camels' skulls in both genders collected from local slaughterhouses in the Kingdom of Saudi Arabia and Iraq. The camel skull was elongated and had a pyramid shape with a base and apex. The bones of the nose were comparatively short, with a short middle and a long lateral process, and serrated rostro-medially. The posterior opening of the nasal cavity was opened caudally and separated into 2 partitions by vomer bone which had a length between 14.33±0.33-18.66±0.33cm. The cavum nasi (CN) comprised 3 turbinates: the dorsal one trimming with a skinny process, totaling 12.76±0.43-13.90±0.20 cm, the ventral was well established, with a total length between 13.6±0.20-17.63±0.08 cm, the middle was ventro-caudal and located rostrally to the ethmoidal turbinate. The longitudinal and transverse axes of ethmoidal bone were between 3.46±0.14-4.7±0.40 cm and 3.66±0.24-3.73±0.23 cm respectively. CN had also four nasal meatuses or passages: dorsal, middle ventral, and a common meatus. The ventral portion that was shaped by a semi-channel formed a sulcus vomeris. Histological records specify that rostral, caudal, and ethmoidal turbinates chiefly have a sensory purpose, whereas the middle turbinate contributes to mucosal defense. The morphometrical, radiological and histochemical information of the nasal region presented in this research will enhance the understanding of nasal cavity patterns that may significantly influence osteoarcheology and also provide information for comparative researches that can be utilized for application in clinical veterinary practices and even in zooarchaeology.

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Introduction

Dromedary camel originates in Iraq (1-7), Saudi Arabia (8), Palestine (9), Egypt (10), Sudan, North Africa, Somaliland, India, and several other states (11). The camel is famous for its capability to persist in the tough atmosphere of the desert (12,13). Commonly, camels are experiencing a reappearance of attention and their significance in the current time might be contingent on an abundant portion of the whole appreciative of their anatomy and physiology (12,13). The cranium is often as the main component of the skeletal representative taxonomy membership, as well as charitable data on variations of animals as a consequence of the collection (14). The anatomical constructions of the skull differ amongst diverse animals. The bones of the skull are subdivided into cranial and facial collections. It cabins the brain, horns, and important structures for hearing, balance, vision, odor, and flavor. The skull moreover procedures margins of the oral and nasal openings and maintains the pharynx and larynx (15). Normally, the arrangement among the bones that form the exterior shape of the nasal area in the skull of the numerous local animals involves the nasal, lacrimal, maxilla, processus nasalis of the incisive, and portion of the frontal bone (16-18). The design and envelopment of these bones in the nasal area differ amongst the animal strains and kinds. Conversely, these differences include the design of pronunciation among the nasal bone and nearby structures such as the maxilla, lacrimal bone, and incisive bone have been indicated as possessing a complete suture or fissure-like feature construction of numerous native mammals (17-20). Numerous readings on the morphometry of skull bones have been taken on in several native kinds for example the cat (21), dog (22), goat (23-28), horse (27), sheep (29) and Iranian cattle and dromedary camel (30-32) to provide standard anatomical data. Explanation of camel anatomy organizes the chief anatomical mentions for veterinary investigation and lecturing databases relating to this kind (33-36). Skull anatomy was done by several other readings provided a complete morphometric explanation of post-natal skull growth and compared the camel skull with those of other native animals. Some authors added diverse morphometrical features of the camel skulls (37-42). An initial study provided just the dissimilar of bones that formula the nasal region of a camel's skull. Still, literature on morphometrical and histochemical features of the internal bones of the camel's skull are inadequate. Even if, the quantity of annually available papers relating to this field is still very little.

Therefore, the current study focused on the osteology of the camel skull facial region, which was a little developing more than in other animals. The current study targeted the examination of the internal olfactory bones of camel skull in Arabic countries, thus donating to satisfying the hole of information in the area of gross and scientific anatomy and histochemically. Therefore, the current effort is charitable a complete picture, descriptive and concluding earlier outcomes, is moreover recording innovative morphometrical and histochemical features of the nasal area capable of playing a noticeable part in the osteological examination, osteoarcheology, radiography and histochemical clarifications and provide features for ultimate comparative readings.

Materials and methods

Ethical approvement

Institute Animal Care and Use Committee in College of Veterinary Medicine, Mosul University, Iraq, has allowed the present work over ethical agreement file No.: UM.VET.2023.122.

Samples collection and skulls preparations

The study was directed at twelve heads of well-camels, aged 1-5 years old of both genders obtained from native abattoirs in the Kingdom of Saudi Arabia and Iraq. The camel's age was estimated through its dental formula (43,44). After removing the skin, the obtained samples were drenched via the hot water drenching procedure for 1-2 hours (23-52). After drenching, the connections between the skull bones and the grooves that form the skull's nasal region were detected in records.

Skull's description and measurements

Description of the whole camel skull was by the unaided eye, and photos were taken via a Sony Cyber-shot® 14.1-megapixel camera as essential and radiography. The drenched skull models were kept in 4% H_2O_2 for 24 hours to create the bones ashen, tracked by sun-drying for 5 days (51,53). These treated skulls were operated for gross anatomical and morphometrical readings, as defined previous (54). Two of camels' heads were used to examine the nasal turbinates histomorphometrically and histochemically. The samples were immediately preserved post-slaughter through an intra-carotid infusion of a 10% formalin solution for (3) days, and subsequently were cautiously dissected. For decalcification, the samples were treated with a diluted formic acid solution at a concentration of 4% and 8% for seventh days at each concentration, then for histological study, each turbinate cut to three parts, rostral, middle, and caudal part. The sections were passed through ascending concentrations of ethyl alcohol in dehydration process, then in xylene for clearance, and in liquid paraffin in an oven at 60°C for allowing the infiltration of the tissue with paraffin. Then the sections were embedded in paraffin, wax molds were cast, and cut using a rotary microtome to obtain tissue slices with a thickness of (6) µm. The histological sections were dried and stained using Hematoxylin-Eosin and Masson's Trichrome stains (55,56). Whole dimensions obtained were stated as mean ±standard error (57).

Overall, a whole of 10 dimensions were taken in the skull of camels in dorsal, lateral, ventral, and medial views following sagittal skull segmenting using a digital Vernier caliper (Resolution 0.01 mm or 0.0005 inches: Accuracy +/- 0.03 mm) and a measuring tape. The recorded measurements of camels' skulls were detailed and illustrated in figures 1-5.

Parameters of camels' skull

Length of Skull (SKL) which is the distance between the highest points of the nuchal crest and the midpoint of the rostral edge of incisive bone. Ethmoid longitudinal axis (ELA) represents the extension of crista galli, the ethmoidal perpendicular plate project into the endocranial cavity, extends dorsally in the nasal septum from the nasal bone to the presphenoid bone internoventrally. Ethmoid transverse axis (ETA) extending from the lateral border of cribriform plate to a second border that crosses the crista galli. Vomer bone length (VL) extension from the dominant point of the sphenovomer suture (Sutura sphenovomeriana) on presphenoid bone to the rostral tip of vomer. Vomer rostral end diameter (VRD) represents the rostral portion of vomer bone inside nasal cavity. Vomer caudal end diameter (VCaD) represents the thick caudal end of the vomer bone from one border to the other in the sphenovomerian suture

(Sutura sphenovomeriana). Turbinate bone length (TL) from the rostral end of the turbinate bone in the rostral portion at the attached point between the incisive bone and nasal bone to the crista galli of the ethmoid bone (union line the ethmoidal turbinate with the ethmoid bone (crista galli). Rostral end diameter of turbinate bone (RTD) the line on the rostral ending of the turbinate bone extends from dorsal edge to a ventral border of the dorsal or ventral turbinate bones. Middle-end diameter of turbinate bone (MTD) the line in the middle of the turbinate bone extends from the ventral border of the dorsal or ventral turbinate bones to the dorsal edge. Caudal end diameter of turbinate bone (CTD) the line in the caudal part of the turbinate bone extends from the ventral edge of dorsal or ventral turbinate bones to the dorsal edge.

Results

In native animals of this study, the skull dimensions presented that the camel's skull was elongated and had a pyramid shaped and four surfaces, the base was the nuchal surface and the apex was the furthest rostral portion of the face. The dorsal surface of the skull might be divided into cranial (face) and caudal (cranium) regions. Length of native camel skull was between 36±1.01- 42±1.15cm. The peripheral structure of nasal region of studied Arabic camels' skulls comprises nasal, incisive lacrimal and maxilla bones along with a portion of the frontal bone. The facial part of skull was shaped through five bones, dorsally, the frontal and nasal bones; caudolaterally, the maxillae and lacrimal bones, while, the incisive bone was rostrolaterally. Frontal bones were located at the edges of the skull and face, situated between the parietal bones to the rear and the nasal bones rostrally. Nasal bones are positioned rostral to the frontal bones and form the roof of the nasal cavity. Individually, each nasal bone articulates with the bone on the opposite side, as well as with the frontal and maxilla and a time with the incisive bone. The bones of the nose were comparatively short, with a long lateral process and a short median at the end. The nasal bones were edged by the maxillary bones laterally, that developed in the nasal area with a restricted design to create the slim dorsolateral edges of the nasal region. Nasal bones were notched rostromedially in camel. Rostrally, the maxilla at inconstant lengths appeared to contribute with the bony opening of the nose (Figure 1).

Two kinds of connection designs were detected, making naso-maxillo-incisive and naso-incisive fissure. First kind was connection of the maxilla to the nasal bone dorsally and the incisive bone rostroventrally to form the naso-maxillo-incisive notch that was shaped. Second kind was connection of nasal and incisive bones to form naso-incisive notch (Figure 1). The maxilla and incisive bones formed a whole connection with the nasal bone, so, the maxillary bones of the camel appeared fused in the rostral nasal aperture (Figure 1). The nasal bones of camels were comparatively slimmer and lengthier (Figures 1-5), these bones end with a small median and elongated lateral processes, accompanied by the rostral distant extra caudal (Figures 1-5). The nasal bones were serrated rostro-medially in camel.

In dorsolateral observing of the skull, two classic combination designs of the facial bones were identified that shaped the maxillo-facial area of the camels' skulls. The 1st kind was naso-incisive shaped by the existence of a certain naso-incisive-maxillary connection, which seemed to be absent in camel. The 2nd kind was the naso- incisive-maxilla notch that was shaped through an interlude of the variable spaces of maxilla realized between the nasal bone and incisive bone (Figure 1).

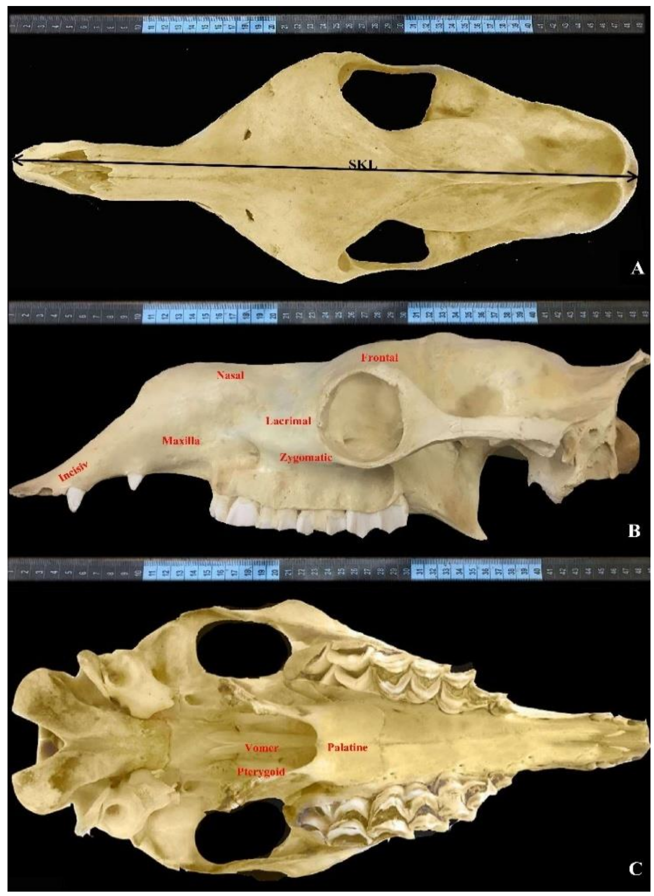

Figure 1: A, B & C are macrophotography showing the dorsal, lateral, and ventral views of adult male skull illustrating the bones of face and cranium, and the length of the skull.

The Dorsum nasi was flunked in front of the orbit and surrounded individually side by a depressed hollow. The nasal bone was condensed, seemed thicker at its end than at its base (Figures 1 and 5), therefore, the rostral nasal process (Processus nasalis) was not obvious in the camel, but there were, as an alternative, 2 minor processes demarcating an incisura.

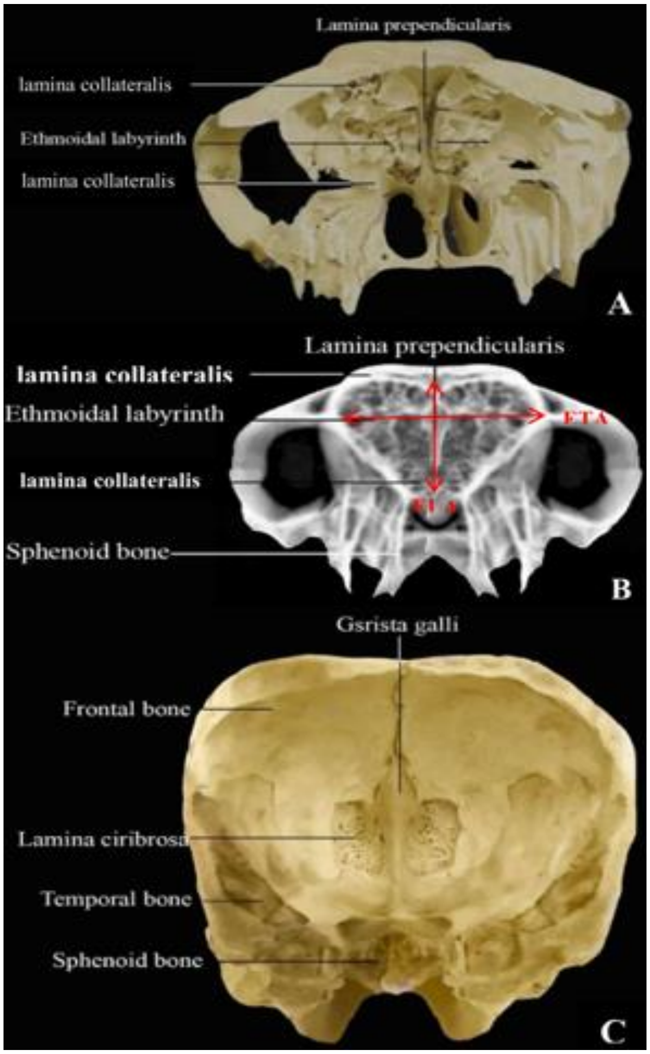

Figure 2: Caudal views of the rostral portion of cranial cavity of adult male skull. Calvarium was removed. A & C Macrophotography, and B X-Ray photograph.

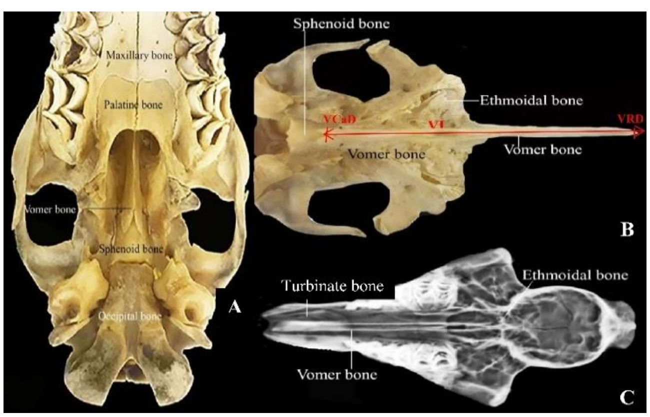

Figure 3: Ventral view of the adult male skull. A & B Macrophotography, and C X-Ray photograph.

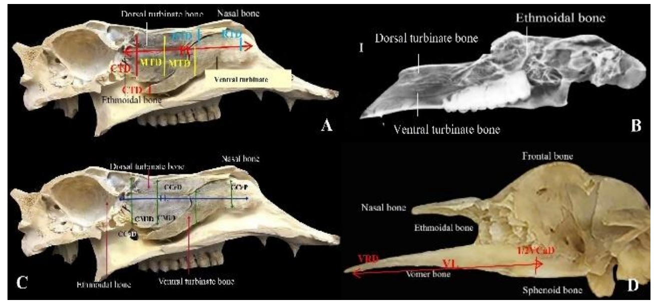

Figure 4: Median section view of male adult skull, showing skull parameters, the vomer and ethmoidal bone separated. A & C Macrophotography, and B X-Ray photograph.

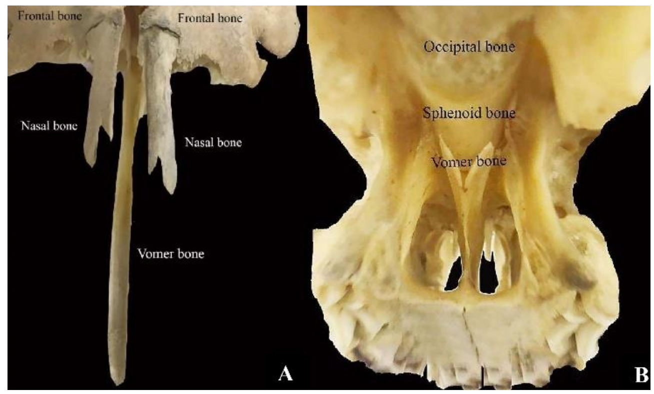

Figure 5: Macrophotography of adult male skull showing the nasal and vomer bones. (A) dorsal and (B) ventral views.

The medial process was shorter and formed a little median concavity in comparison with the opposite side, whereas the lateral one was higher. The foramina were detected on the lateral aspect of nasal bone (Figure 1A) that appear to be usual in Arabic camel. The rostral opening of the nose was typical in camel comprising of the maxillary bone that splits the nasal bone from the incisive in adult camels. More profound characters appeared in this foramen, first, a distinctive formed vomer bone (Vomer), similar to a semitubular structure, and second the border of the ventro-rostral turbinate (Figure 1C). Furthermore, the absence of incisive bones fusion rostrally.

The intermediate area matched the caudal opening of the nasopharyngeal duct (Choanae) of the pharynx. The opening of the choanae wasn't enclosed caudally in camel, and was separated into 2 partitions by vomer bone. This subsequently developed extra caudally and existed at its termination in a specific form (Figures 2, 3 and 5). This comprised 2 processes, big and slim that shelter the base sphenoid body without combining it. The length of the vomer bone was between 14.33±0.33-18.66±0.33cm. While the caudal end diameter of the vomer bone was between 0.8±0.01-1.76±0.08 cm, and the rostral end diameter was between 0.3±0.01-0.43±0.03 cm.

The facial area offered an expansion of choanae and was shaped by: the horizontal portion of the palatine bone; the palatine and the alveolar processes of the maxillary bone; and the incisive bone. The median palatine suture was shaped at outlines of the junction of the two palatine bones and of the two maxillae. This suture is prolonged rostrally by the inter-incisive suture. The latter suture was enclosed at each side by a palatine notch and ended rostrally in an exclusive inter-incisive notch. The rooftop of the skull appearances in its cranial cavity an advanced internal sagittal crest; whereas the rostral wall was hollowed out into 2 deep ethmoidal fossae (Fossa ethmoidales), divided by a ridge of the ethmoidal bone: Crista Galli that prolonged to the inner lamina of the frontal bone (Figure 2).

The nasal cavity is prolonged from nostrils to the nasopharyngeal opening (Figures 1 and 5). It comprised three turbinates: the dorsal turbinate trimmings with a skinny process, the total length of was between 12.76±0.43-13.90±0.20 cm, while the rostral, middle, and caudal end diameter was between 2.9±0.23-1.13±0.06 cm, 4.4±0.30-2.76±0.08 cm, 4.6±0.70-5.5±0.51cm respectively. The ventro-rostral turbinate portion of turbinate bone was firmly established. It had a total length between 13.6±0.20-17.63±0.08 cm with rostral, middle, and caudal end diameters between 0.66±0.06-3.66±0.12 cm, 3.08±0.11-4.06±0.06 cm, 2.3±0.06-1.2±0.17 cm respectively. The middle nasal turbinate located ventrocaudally, rostral to the turbinate of the ethmoidal bone. The current research discovered approximately significant variances of both the position and shape of these turbinates. The ethmoid bone featured additional well-established turbinate situated caudal to the middle turbinate (Figure 1). The additional turbinate was similar to the 4th nasal turbinate in camels, measured also, where the longitudinal axis of ethmoidal bone was between 3.46±0.14-4.7±0.40 cm, while the transverse axis of ethmoidal bone was between 3.66±0.24-3.73±0.23 cm (Figures 3 and 5). Dissimilar to the ventral turbinate, the middle and dorsal turbinates, each of them considers as a sinus partition. The nasal cavity of camel contained also four nasal meatuses: dorsal, ventral, intermediate, and a common nasal meatus. The intermediate meatus was separated in its terminal part into dorsal and ventral meatuses adjoining the intermediate nasal turbinate. The common meatus was positioned medially to the nasal septum. Its ventral portion was shaped by a like-channel-formed vomeral groove.

The histological examining showed that the nasal cavity in the camel consisted of three main parts: the nasal vestibule, which was the widest anterior part of the nasal cavity and covered by hairy skin. Nasal vestibule was followed by a transitional part lined with stratified cuboidal to stratified columnar epithelium, which was directly transformed into respiratory epithelium at the respiratory region. The caudal extension of the vestibule represented the main part of the true nasal cavity in the camel. It was mainly occupied by the nasal turbinates, followed by the olfactory region lined with olfactory epithelium. The histological study was conducted on the nasal turbinates that were covered by different types of epithelia, with varying positions of the nasal turbinates, which were divided into four turbinates according to their anatomical location inside the nasal cavity: a dorsal turbinate, a middle turbinate, a ventral turbinate, and an ethmoid turbinate.

Histological results showed that all turbinates were covered on both sides with different types of epithelia, directly underneath which was connective tissue composed of colloidal fibers, muscle fibers, and nerve endings interspersed with tubular secretory glands followed by hyaline cartilage. The anterior part of the dorsal, middle, and ventral turbinates was taken to clarify the tissue structures. The outer epithelium of the dorsal turbinate was stratified cuboidal epithelium consisting of several rows of cuboidal cells with centrally located nuclei. In contrast, the inner epithelium was respiratory (pseudostratified ciliated columnar epithelium) consisting of a row of basal cells settled on a basement membrane between which extended a large number of ciliated columnar cells with an oval nucleus. It was noted that there were goblet cells resembling a flask to secrete mucus that covers the surface of the epithelium. Neuroendocrine cells were also seen next to the basal cells. The outer epithelium of the middle turbinate was the olfactory epithelium, consisting of basal cells responsible for regenerating olfactory neurons, that appeared ciliated on their outer surface, in addition to the presence of supporting cells in the shape of a spindle that was present around the olfactory neurons, brush cells were found that have microvilli. The inner epithelium of the middle turbinate and the epithelium covering the sides of the ventral turbinate were respiratory described previously. The epithelial thickness varied according to its location within the turbinates, but the outer epithelium that covers the dorsal aspect of the turbinate was thicker than the inner epithelium that covers the ventral aspect of the epithelium, the outer as well as inner epithelia of anterior part of the ventral turbinates statistically, appeared to be highest compared to other regions (Table 1). Directly under the epithelium and on both sides, there was connective tissue interspersed with serous and mucous secretory units (Ssu)(Msu) of the tubular glands. These glands have different diameters depending on their location, but they appeared with higher diameters in the inner part of the turbinate compared to their diameters under the outer epithelium. These units were surrounded by myoepithelial cells, in addition to the presence of distinct ducts for these glands. Secretory units' diameters of all turbinates also differed according to its location, but it appeared with higher diameters in the dorsal part of the turbinate and was lost in some parts (Table 1).

The hyaline cartilage appeared in the middle of the turbinate and was closer to the inner surface than to the outer or dorsal surface of the turbinate, and its thickness differed according to the areas of its extension, but it appeared with a high thickness in the anterior parts of the dorsal turbinate and low thickness in the anterior part of the middle and ventral turbinates (Table 1) (Figure 6).

The outer epithelium of the middle part of the three turbinates was transitional between the respiratory epithelium and the olfactory epithelium. All turbinates covered by respiratory epithelium from inner and outer surfaces except the middle part of the middle turbinate which covered by olfactory epithelium, the thickness of the epithelium varied. However, the outer or covering epithelium of the dorsal surface of the turbinate was thicker than the inner. Statistically, the total diameter of the external epithelium of middle part of ventral turbinate appeared to be the highest compared to internal epithelium (Table 1). Histologically the tissue structures were similar in the different parts of the turbinate, but statistical differences appeared.

The mucous and serous secretory units of the tubular glands, which appeared only on the outer side of the ventral turbinate, were surrounded by myoepithelial cells, in addition to the presence of distinct ducts for these glands, where the mucus material is transported on the surface of the epithelium. Its diameters also differ according to its location. Still, it appeared a high diameter in the middle part of middle turbinate (Table 1).

The hyaline cartilage that appeared in the middle of the turbinate, branched in some places from the middle part of the turbinate, its thickness varied according to the areas of its extension, but it appeared with a high thickness in the middle parts of the dorsal turbinate and decreased gradually (Table 1 and Figure 7).

The outer epithelium of the posterior part of the three turbinates is transitional, consisting of the olfactory and respiratory epithelium, depending on the location of the turbinate wrapping, and the inner epithelium of the three turbinates was respiratory epithelium. However, the outer or covering epithelium of the dorsal surface of the turbinate was thicker than the inner epithelium and the epithelium of caudal part of ventral turbinate, it showed a significant difference compared to other parts of the turbinates of the nasal cavity.

The mucous and serous secretory units of the tubular glands may be found in other side of dorsal and middle turbinate, while appeared only on the outer side of the ventral turbinate and did not appear beneath the inner epithelium of the same turbinate. These units were surrounded by myoepithelial cells, and their diameters also differ. Still, it appeared with higher diameters under the inner epithelium of the caudal part of dorsal and middle turbinates (Table 1 and Figure 8).

The ethmoid turbinate appeared small, consisting of two parts: an anterior or rostral part with a thick diameter and a very thin terminal part. In the middle, there is a cartilage with a very small diameter. It is lost in some places of the turbinate. The turbinate was covered on both sides by the olfactory epithelium, which appeared thicker on the inner side compared to the outer epithelium. Only serous secretory units were found, under the inner epithelium of the anterior part, and they were lost in the last part of the turbinate and appeared with small diameters (Table 1 and Figure 9).

Table 1: The histomorphometrical measurements of the nasal turbinates

Turbinate	Part	Mean ± Standard Error					
		TD	CD	DSE	DSI	DEE	DIE
Rostral	Dorsal	1533±50.8	220.6±3.4	43.2±1.4	52.6±1.7	61.2±4.2	44.3±2.2
	Middle	455.2±3.4	191.4±8.2	51.8±3.4	54.7±1.8	42.1±1.9	40.0±1.3
	Ventral	824.8±43.1	66.4±3.4	44.2±1.7	45.2±1.5	76.3±2.9	57.1±1.5
Middle	Dorsal	1258.4±43.3	105.9±9.4	62.4±2.4	63.6±1.9	42.9±2.0	37.3±1.4
	Middle	415.3±22.8	67.4±4.1	73.4±1.6	76.1±2.6	40.9±2.7	34.7±1.6
	Ventral	491.6±15.1	59.4±6.5	59.8±1.4	0.0±0.0	53.3±1.7	40.9±1.7
Caudal	Dorsal	614.4±20.2	101.8±4.6	74.9±3.2	82.6±1.7	46.2±2.5	34.2±3.2
	Middle	381.7±13.7	56.6±3.1	80.1±1.9	79.7±3.1	41.4±1.7	30.0±1.2
	Ventral	449.7±14.91	46.7±4.56	72.8±1.60	0.0±0.0	57.3±1.48	44.5±2.24
Ethmoid		271.3±10.9	37.9±2.8	0.0±0.0	28.4±1.3	65.4±3.1	60.9±0.7

Turbinate diameter (TD); Cartilage diameter (CD); Diameter of the secretory units under the external epithelium (DSE); Diameter of the secretory units under the internal epithelium (DSI); Total diameter of the external epithelium (DEE); Total diameter of the internal epithelium (DIE).

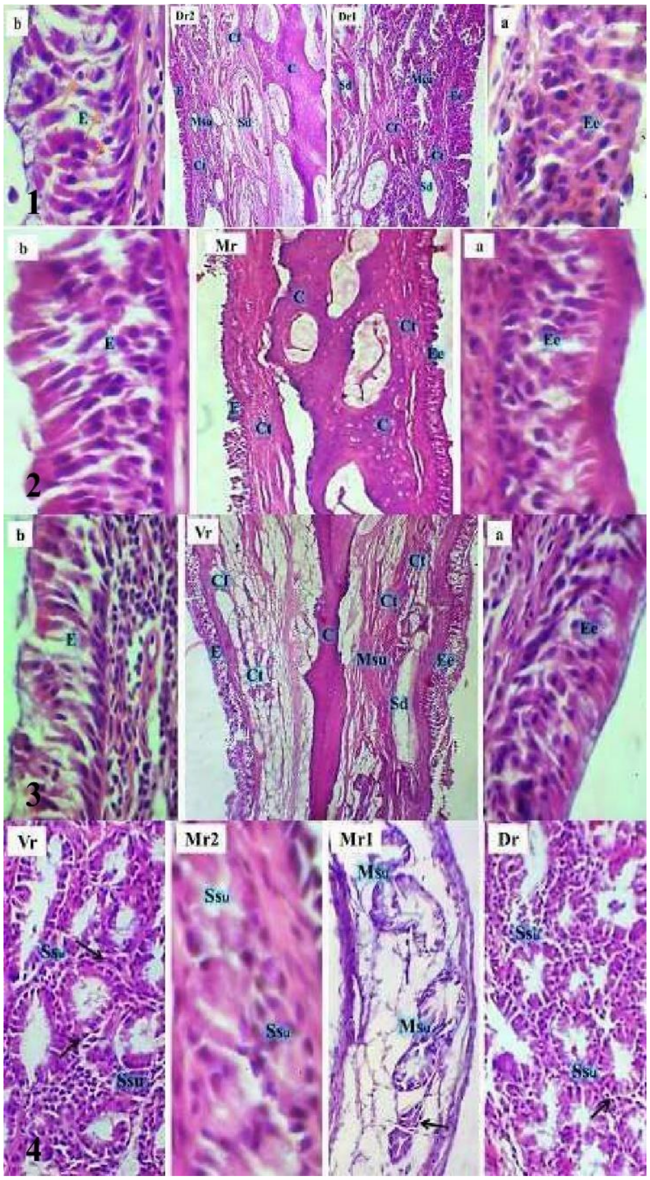

Figure 6: Microphotographs of the rostral parts of (1) dorsal (Dr), (2) middle (Mr), and (3) ventral (Vr) turbinate, Dr1 dorsal part of the dorsal turbinate, Dr2 ventral part of dorsal turbinate, a and b enlarged epithelium; show in part 1: the outer stratified cuboidal epithelium Ee, the inner respiratory epithelium E; in part 2: the outer olfactory epithelium Ee, the inner respiratory epithelium E; in part 3: the outer respiratory epithelium Ee, the inner respiratory epithelium E, the colloidal or collagen fibers Cf, the connective tissue Ct, the muco-secretory units Msu, the cartilage C, the secretory ducts Sd, the neuroendocrine cells Nec (orange arrow). Dr1, Dr2, Mr, Vr (40X), a and b (400X). Part 4: Microphotographs of the mucous secretory units Msu and serous secretory units Ssu of the tubular glands located in the nasal turbinates, myoepithelial cells (black arrow), Hematoxylin and Eosin. 100X.

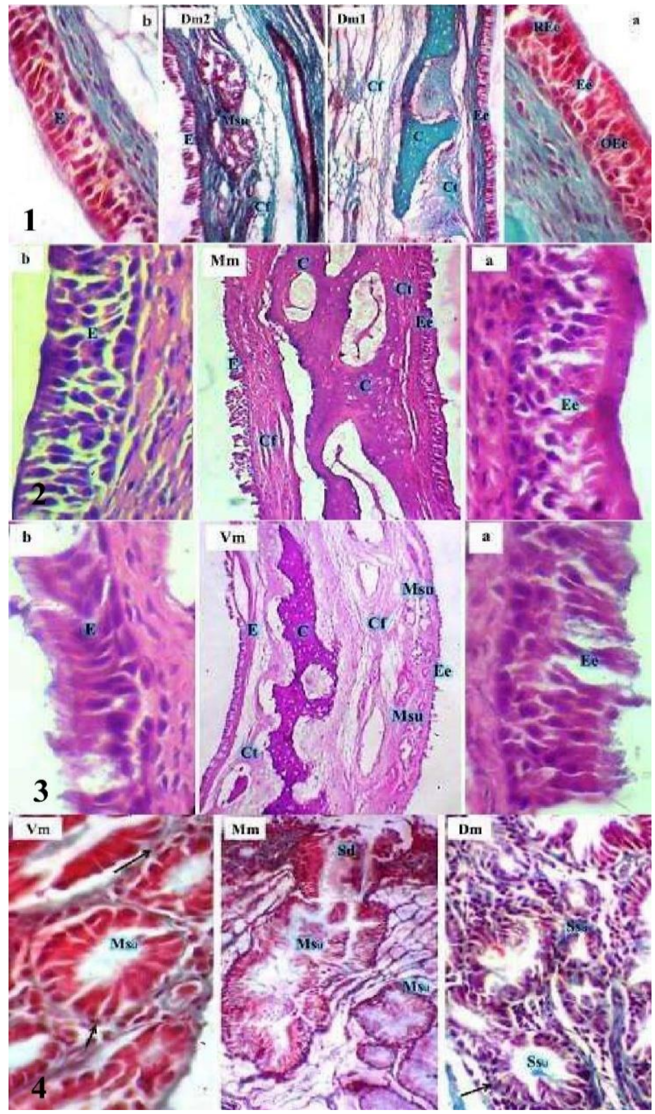

Figure 7: Microphotographs of the middle part of (1) dorsal (Dm), (2) middle (Mm), and (3) ventral (Vm) turbinate, Dm1 dorsal part of the dorsal turbinate, Dm2 ventral part of dorsal turbinate, a and b enlarged epithelium; show in part 1: the external respiratory epithelium REe & olfactory epithelium OEe , Ee, the internal respiratory epithelial tissue E; in part 2: the external olfactory epithelium Ee, the internal respiratory epithelial tissue E; in part 3: the outer respiratory epithelial tissue Ee, the internal respiratory epithelial tissue E , the colloidal or collagen fibers Cf, the connective tissue Ct, the muco-secretory units Msu, the cartilage C, the neuroendocrine cells Nec (orange arrow), the external olfactory epithelium Ee. Part 4: Microphotographs of the mucous secretory units Msu and serous secretory units Ssu, the secretory ducts Sd of the tubular glands located in the nasal turbinates' myoepithelial cells (black arrow). Part 2&3 Hematoxylin and Eosin. Part 1&4 Masson trichrome stain. Dm1, Dm2, Mm, Vm (40X), a and b (400X). Part 4 100X.

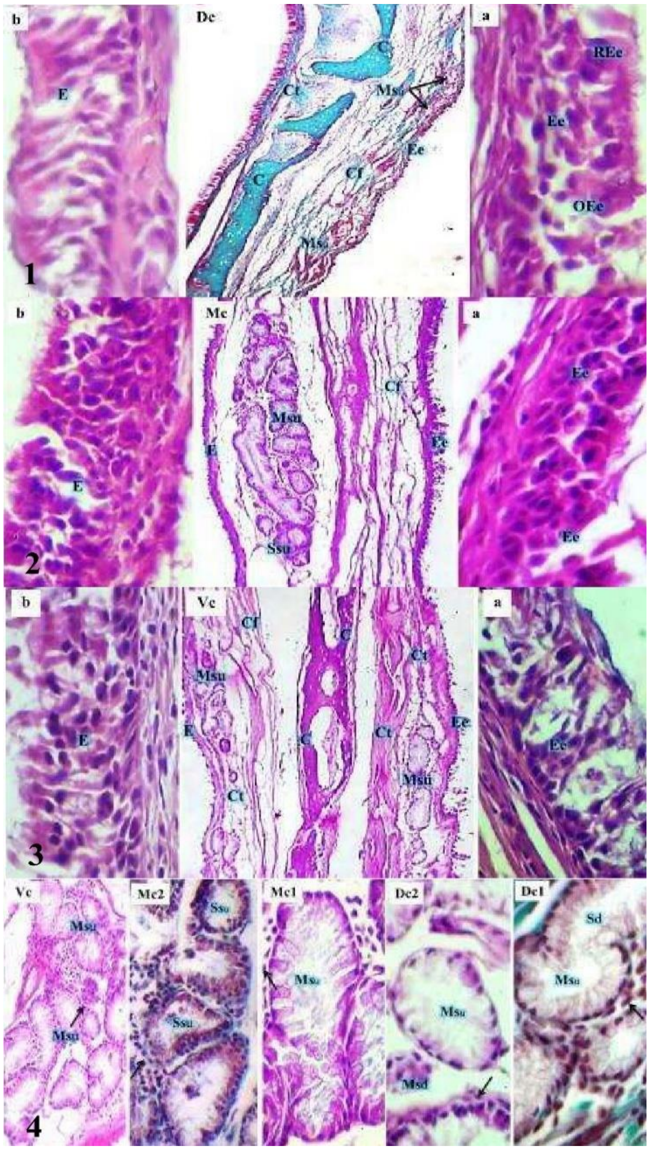

Figure 8: Microphotographs of the Dc caudal part of the dorsal turbinate, Mc caudal part of middle turbinate, Vc caudal part of ventral turbinate , a and b enlarged epithelium; show in part 1: the external respiratory epithelial tissue REe & olfactory epithelial tissue OEe , Ee, the internal respiratory epithelium E; in part 2: the external olfactory epithelium Ee, the inner respiratory epithelium E; in part 3: the external respiratory epithelial tissue Ee, the external respiratory epithelium E , the colloidal or collagen fibers Cf, the connective tissue Ct, the muco-secretory units Msu ,serous secretory units Ssu, the cartilage C. Part 4: Microphotographs of the mucous secretory units Msu and serous secretory units Ssu , the secretory ducts Sd of the tubular glands located in the nasal turbinates myoepithelial cells (black arrow). Part 2&3 Hematoxylin and Eosin. Part 1: Dc & part 4: Dc1 & Mc2 Masson Trichrome stain. Dc, Mc, Vc (40X), a and b (400X). Part 4 100X.

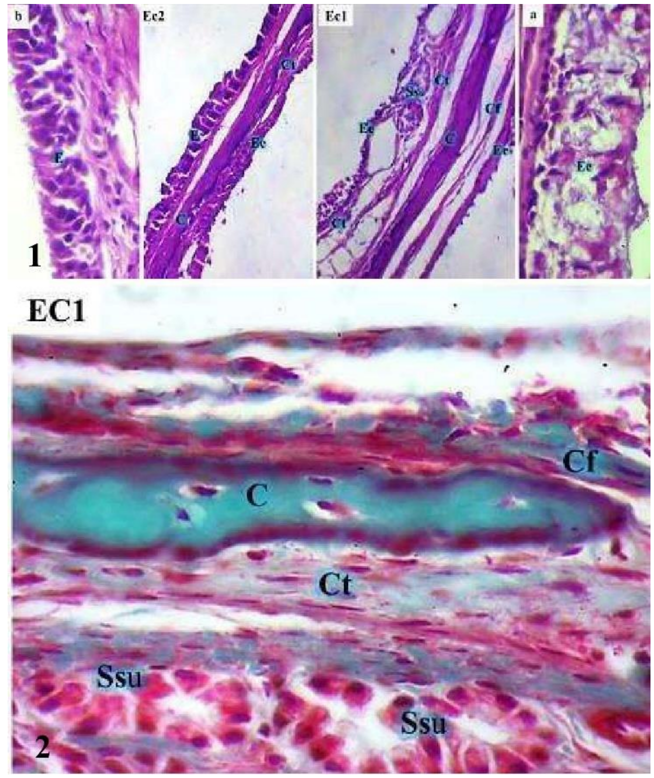

Figure 9: Part 1 and 2: Microphotographs of the ethmoidal turbinate, rostral part Ec1 and its caudal part Ec2, a and b enlarged epithelium; shows the external olfactory epithelium Ee, the internal olfactory epithelium E, the cartilage C, the colloidal fibers Cf, the connective tissue Ct, serous secretory units Ssu. Part 1: Ec1 & Ec2 40X, a and b 400X, Hematoxylin and Eosin; Part 2: EC1 100X, Masson's Trichrome stain.

Discussion

The facial skeleton consists of several paired bones as the maxilla, nasal, zygomatic, and others described in horse (19), dog (20), blackbuck (48,49), ox (58), ruminants (59), and chital (60). The nasal bones were notched rostromedially in camel and ox (58). In the current study, the design of the connection between the bones near the nasal area was engrossed. Commonly, the nasal area of skull consists of the nasal bone, nasal process of incisive bone, and the rostral end of the frontal bone in utmost native mammals (16,18). Nasofrontal portion a piece of frontal bone develops externally in direction of the orbits to a larger degree to the width of the two frontal bones located between the dorsal boundaries of orbit was bigger than in horse (61). Nasal bones of the camels were comparatively slimmer and lengthier than in the cattle and horses as similarly detected (61,62). As well as the nasal bones are closed to different bones of the cattle (19,61) and goats (63) somewhere the nasal bones were described as not being confidently attached to nearby bones. In camels, these bones end with a tiny median and elongated lateral processes with the anterior distant extra caudal matched to whatever was informed in cattle to be virtually even, although in horse it was tall and sharp spreading outside the naso-incisive incisura (19,61). This limitation of nasal bone in the camel belongs to the extending and reduction of the nasal fissure.

Sphenoid, ethmoid, and parietal bones look like that of an ox (58). The nasal bones were serrated rostro-medially in camel as described previously in ox (58). Nevertheless, they have pointed ends in horse (19) and half-spherical end in dog (20). In the current research, incisive bone was detected to the form a connection dorso-caudally with the maxillary bone only or with the maxillary and nasal bones, an existence wasn't realized in sheep and the cattle (19,61). Incisive and palatine fissures were minor and slimmer compared to those in cattle

The maxillary body was smaller in the camels than in the cattle and horses (61). Dorsolateral observing of the skull identified 2 classic combination designs of facial bones (incisive, nasal, and maxillary) that shaped the maxillary and facial area of the skulls in camels. The first kind was naso-incisive shaped by existence of ~~a~~ certain naso -incisive- -maxillary connection (36).

The second kind was the naso-maxillo-incisive fissure, that was shaped by interlude of variable spaces of maxillary bone realized between the incisive and nasal bones. The previous was comparable to which defined in the goats (24-25,63), whereas the last look like the morphological organization in goat (18), horses and cattle (19,61). The complete information demonstrates resemblances with other native mammals but moreover numerous individualities in camel head osteology.

The dorsal wall of the nose was recessive in front of the orbit and was individually encircled by a depressed concavity on each side. Nasal bone was condensed, seemed bigger at the free (rostral) end than at the base, therefore, the nasal process that was well developing of horses, sheep and goat, and pigs (64) was not obvious in the camel. But there were, as an alternative, two minor processes demarcating a fissure; the medial process was shorter and a little median concavity that contrasted with the opposite side, whereas the lateral process was higher. A like explanation was informed (33), in the camel (34) in the Bactrian camel. The foramina were detected on the lateral side of the nasal bone, informed a bilateral and significantly large foramen in the dorsal wall of camel nose (40). Similar foramens are present in the Red Sokoto goat (28), on the other hand it is almost usual in Arabic camels.

The interior foramen presents in the nose was atypical in camel comprising maxillary bone, in adults, the nasal bone from the incisive bone splits. Also, more profound in this foramen, looks, first, a distinctive formed vomer, similar to a 1/2 channel, and second the border of the rostro-ventral -turbinate. Further at the rostral end, there wasn't combination of the incisive bones viewing so a foramen of the inter-incisive incisura like example in the ruminants and pig (19, 64).

The notes of maxillary bone of camel appearance that this subsequently**,** found process of nasal bone that developed contrarily rendering to the age. When the animal is becoming mature, the process develops lengthier and bigger and exchanges dorso-rostrally getting its greatest distance in extra elderly camels in that it was inserted between the nasal and the incisive bones. So, in camel, maxillary bone was combined in the external orifice of the nose. In 20 percent of the mature camel, there was a certain nasoincisivomaxillary connection whereas, in the remaining eighty percent a naso-maxillo-incisive fissure shaped by an intermission of the adjustable spaces of maxillary bone was observed between the incisive and the nasal bones (40). These variances as informed in the present study, were a significance of age-associated growth of the maxillary bone's nasal process (34).

Nasal cavity is prolonged from its external opening of the nose to the nasopharyngeal opening. It comprised 3 turbinates: the dorsal turbinate trimmings with a skinny process, the total length of was between 12.76±0.43 to 13.90±0.20 cm, while the rostral, middle, and caudal end diameter was between 2.9±0.23 to 1.13±0.06 cm, 4.4±0.30 to 2.76±0.08 cm, 4.6±0.70 to 5.5±0.51cm respectively. The rostroventral (ventral) turbinate was well established, it had a total length between 13.6±0.20 to 17.63±0.08 cm with rostral, middle, and caudal end diameters between 0.66±0.06 to 3.66±0.12 cm, 3.08±0.11 to 4.06±0.06 cm, 2.3±0.06 to 1.2±0.17 cm respectively. The middle nasal turbinate was ventro-caudal and located rostrally to the turbinate of the ethmoidal bone. The measured of anatomical structure of camel's turbinate in comparison to that of other native mammals (33,65). The current research discovered approximately significant variances of both the position and form of these turbinates. The ethmoid bone formed additional well-established turbinate situated caudally to middle turbinate. This middle turbinate was measured in Bactrian camel as fourth nasal turbinate (34), and also measured in the current study the longitudinal axis of ethmoidal bone was between 3.46±0.14 to 4.7±0.40 cm, while the transverse axis of ethmoidal bone was between 3.66±0.24 to 3.73±0.23 cm. Dissimilar to ventral, the dorsal and middle turbinates consider each a sinus partition. This outcome was presented by consuming of the computed tomography (66). The proper nasal cavity of the camel expresses too four nasal meatuses, were the dorsal, the ventral, the middle, and a common nasal meatus. Middle nasal meatus was separated caudally into a dorsal nasal meatus and ventral nasal meatus adjoining of the middle nasal turbinate. While the common nasal meatus only in opposition on both sides of nasal septum medially to other turbinates. Also, it's ventral portion was shaped by a semi-channel-formed vomeral groove. Parallel agreement of the turbinate has been informed in Bactrian camel (34) and lama

(67) in that the ventral turbinate appeared to be less established than in the camel. The nasal turbinates are important for reducing the loss of respiratory heat and water (68). Conservation of heat and water is presumed to be more important in species adapted to extremely dry habitats, as conserving limited resources is critical to the survival of species in such habitats. The researchers concluded that conserving water in a dry environment is the main driver behind this adaptation. Larger nasal cavities allow for larger turbinates, thus conserving more water. So that, the size of the turbinate may be a result of either heat or water retention, or both. In this case, heat retention may be the major factor. Thus, adaptation to local temperature changes may influence the development of micro-anatomical structures important for heat exchange. Evolutionary adaptation to habitats likely led to the emergence of more specialized structures for heat exchange (69). Thus, larger turbinates may reduce the distance between the center of airflow and mucosal surfaces (70). For example, the surface area of turbinate in carnivores is smaller in large species, probably due to the larger body volume-to-surface area ratio and slower respiration rates. Consequently, heat dissipation and respiratory water losses would be lower, and the need for complex turbinates would not be as significant (71).

The dorsal turbinate had a cartilaginous center covered by a layer of lamina propria and a surface layer of keratinized squamous epithelium as represent a continuation of the keratinized outer skin. The outer epithelium covering the dorsal faces of the turbinates was thicker than the inner epithelium that covers the ventral aspect of the turbinates, its thickness may be attributed in bearing the force of air pushing into the nasal cavity. Directly under the epithelium the serous secretory units were surrounded by myoepithelial cells to squeeze the secretory unit and facilitate the secretion of liquid substance through their ducts where the mucus was transferred to the surface of the epithelium to protect and get rid of foreign bodies and responsible for humidifying the air entering the respiratory tract. The dorsal nasal turbinates are important as an airway barrier that directs airflow to specific parts of nasal cavity. Dorsal nasal turbinate's direct airflow over tip of the nose, which acts as a reservoir for secretions of the nasal glands (72). Consequently, air becomes humidified as it passes over this part before continuing to the middle turbinates. This may be important to protect the respiratory epithelium in the middle turbinates from inhaled air that is too dry. This may be a result of habitat adaptation, similar to the desert-adapted songbirds investigated by (73). The outer epithelium of the middle part of the three turbinates was transitional between the respiratory epithelium and olfactory epithelium, composed of basal cells responsible for the regeneration of olfactory neurons and damaged cells, and olfactory sensory neurons and sensory cilia, which appear ciliated on their outer surface and are responsible for receiving odors (74). In addition to the presence of supporting cells around the olfactory neurons to provide them with protection, brush-bordered cells are found to transmit the sensation of chemical substances in the nasal cavity (75). Immediately beneath the epithelium of the ventral turbinate and on both sides, there were mucous and serous secretory units of the tubular glands, which appear only on the outer side of the ventral turbinate, and do not appear beneath the inner epithelium, this may be regarded to unnecessity for mucus secretion in this area of the nasal cavity, this result agrees with the results of study on one humped camel in Egypt (75). The middle and ventral turbinates, like the dorsal turbinates, consist of hyaline cartilage covered by a mucous membrane and respiratory epithelium facing the airflow. In the middle part of ethmoid turbinate, there was a cartilage with a very small diameter that lost in some places of the turbinate. The ethmoidal turbinate was covered on both sides by the olfactory epithelium, which appeared thicker on the inner side compared to the outer epithelium. Olfactory receptor cells are reformed neurons scattered inside the olfactory epithelium. The bodies of these olfactory perception cells exist within the epithelial tissue and have apical cilia that developed on top of the surface epithelium. Axons of nerve prolonged from the olfactory perception cells into the lamina propria and connect with other axons to create collectively the olfactory nerve, which runs in sequence over holes in cribriform plate of ethmoidal bone at rostral wall of cranium and passes in the olfactory bulb of the brain. In this manner, odors are sensed by olfactory receptors of the cells and transferred through axons leading to the brain where these scents are transformed to the olfactory perception (74). Only serous secretory units were found, under the inner epithelium of the anterior part, and they were lost in the last part of the ethmoidal turbinate to moisten the surface and wash away the previously perceived odors (75).

In brief, our records described the shape of the skull and the internal olfactory region of camels in Arabic countries. Histological records specify that the rostral, caudal, and ethmoid turbinates chiefly have a sensory purpose, and the middle turbinate contributes to mucosal defense. These findings given the significance importance for morphological and clinical anatomy, reproductive literature, and physical characterizations of the camels.

Conclusion

It can be determined from the current work that the morphology of the camel skull varies from the ruminants; but rare comparable features were detected in canine, equine, and swine. All over this study, also reveals numerous individualities of the camel skull. The findings suggest that it is indeed important to maintain a temperature gradient in the nasal mucosa so that heat dissipation remains within limits. The complete result records of this study organize a particular morphometrical and histochemical mention and add to worthy information of this field. Instead, these records could be valuable in diverse fields for example osteoarcheology, Advanced research, basic and practical of anatomy, and histochemistry of camel. These morphometric records delivered in the current research on the skull of camel can contribute to additional investigation in the field of morphological, practical anatomy, and histochemistry on wild and farm animals. The olfactory bones can be determined that the results of this research would contribute to the comparative researches with additional farm animals and can be practicable in the training of the medical veterinary and the zooarchaeology.

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Conflicts of interest

The authors declare no conflict of interest.

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دراسة شكلية قياسية وإشعاعية وكيميائية نسيجية للعظام الشمية الداخلية في الإبل (الجمل وحيد السنام)

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الخلاصة

صممت الدراسة الحالية لتوضيح القياس الشكلي والإشعاعي والكيميائي النسيجي للعظام الشمية الداخلية لجمجمة الجمل على ١٢ جمجمة من كلا الجنسين تم جمعها من المسالخ المحلية في المملكة العربية السعودية والعراق. كانت جمجمة الجمل طولية، ولها شكل هرمي بقاعدة وقمة. كانت عظام الأنف قصيرة نسبيا، مع نتوء وسطي قصير ونتوء جانبي طويل، وهو عظم مسنن أماميا ووسطيا. لم تكن الفتحة الخلفية للتجويف الأنفي مغلقة من الناحية الخلفية وقسمت إلى قسمين بواسطة عظم الميكعة الذي يتراوح طوله بين ١٤,٣٣±٠,٣٣-١٨,٦٦±٠,٣٣ سم. يتكون التجويف الأنفي من ثلاثة محارات: محارة ظهرية ذات بروز رفيع، يبلغ طولها الإجمالي ما بين ١٢,٧٦±٠,٤٣-١٣,٩٠±٠,٢٠ سم، كانت المحارة البطنية أكثر بروزا وبلغ طولها الإجمالي ما بين ١٣,٦±٠,٢٠-١٧,٦٣±٠,٠٨ سم. المحارة الوسطى التي كانت بطنية وذيلية وتقع اماميا لمحارة العظم الغربالي. كان المحور الطولي والعرضي للعظم الغربالي بين ٣,٤٦±٠,١٤-٤,٧±٠,٤٠ سم و٣,٦٦±٠,٢٤-٣,٧٣±٠,٢٣ سم على التوالي. كان لدى التجويف الأنفي أيضا أربع ممرات أنفية: ظهري، بطني، وسطي، ومشترك، والجزء البطني الذي يتشكل بواسطة شبه قناة يشكل الميزاب الميكعي. تشير الدراسة النسيجية إلى أن المحارات الأمامية والخلفية والغربالية لها وظيفة حسية بشكل أساسي، وأن المحارة الوسطى تساهم في الدفاع عن الغشاء المخاطي. ستساهم المعلومات الشكلية القياسية والإشعاعية والكيميائية النسيجية لمنطقة الأنف المقدمة في هذه الدراسة في معرفة نمط تجويف الأنف الذي يمكن أن يلعب دورا بارزا في علم آثار العظام كما تقدم معلومات للدراسات المقارنة التي يمكن استخدامها للتطبيق في الممارسات البيطرية السريرية وحتى في علم آثار الحيوان.