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# Anatomical Peculiarities of the Dromedary Camel (*Camelus dromedarius*) Nasal Structure: A Study Reveals Unique Proboscis-like Structure

Fatgzim Latifi[1], Ibrahim A. Girgiri[2], Eman A. Eshrah[3*]

[1]*Department of Veterinary Medicine, Faculty of Agriculture and Veterinary, University of Prishtina" Hasan Prishtina ", Prishtina Kosovo,*
[2]*Department of Veterinary Anatomy, Faculty of Veterinary Medicine, University of Maiduguri, PMB 1069, Nigeria.*
[3]*Department of Anatomy and Embryology, Faculty of Veterinary Medicine, Benha University, Toukh 13736, Egypt.*

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**ABSTRACT**

The knowledge of the proboscis morphology is of a particular significance, especially in the field of comparative veterinary anatomy and rhinology. The proboscis is a specialized nasal organ, which has several anatomical modifications that enable the animal to withstand the adverse climatic conditions. Remarkably, the anatomy of the camel nose is distinct in comparison with ruminant and other domestic animals. This has been attributed to the essential proboscideal criteria to which the camel nose possesses. However, little is known about the proboscis-like structure of the dromedarian nose. Therefore, the aim of the study was to elucidate the idea that camel nose is best interpreted as a sort of proboscis.

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## Introduction

Mammalian noses differed on the basis of their structural morphology. Some species have a specialized nose such as proboscis or proboscideal nose as an adaptive feature against dusty habitats and extreme environmental conditions. Such specialized organs are found in a group of animals known as the proboscis-bearing mammals, such as, Moose (*Alces alces*), dik-dik (*Madqua guntheri smithi*), and Saiga antelope (Saiga tatarica). The noses of the aforementioned species are usually large, muscular and drop over their upper lips (Clifford, 2003). The proboscis similarly has major transformation of the internal anatomy of the nasal cavity. The nostrils are the narrowest portion of the nasal cavity, which forms an enlarged space internally. The enlarged nostrils are generally accompanied by specialized musculature, reduction of the nasal bones and cartilages, as well as special sacs and air recesses (Witmer *et al.*, 1999; Clifford and Witmer, 2004). Additionally, the nasal vestibule dominates the rostral half of the nasal cavity with a set of nasal conchae restricted to the caudal third of the cavity (Clifford, 2003; Clifford and Witmer, 2004). Together, these anatomical features allow unique biomechanical properties shared by such specialized proboscideal noses (Kier andSmith, 1985; Witmer *et al.*, 1999). The highly mobile upper lip and nostrils could be helpful in browsing and stereolfaction (Clifford, 2003). The nostrils are capable of being compressed, and a complete narial closure is also possible (Witmer *et al.*, 1999; Clifford, 2003; Clifford and Witmer, 2004).

Narial closure is atypical feature missing in non-proboscis bearing mammalian species. Instead, the domestic animals, including ruminant possess a group of muscles that are only limited to nasal dilation (Nickel *et al.*, 1979; Dyce *et al.*, 2009). The narial muscle in these animals generally gives attachment to a complete bony and cartilaginous skeleton, hence rendering the nostril stiffed and opened. However, unlike the domestic ruminants, camels are capable of narial closure (Eshra and Badawy, 2014). The Latter study also reveals that the anatomical structure underlies such capability in camels are closely related to those of the proboscis bearing animals.

There are cumulative events that the camel nose is best interpreted as a sort of proboscis. Accordingly, studying the camel nasal anatomy would provide an addition to the field of comparative biology. However, little is known about the proboscis like structure of the dromedarian nose. Therefore, the aim of this study was to review the anatomical peculiarities

*Corresponding author: Eman A. Eshrah
*E-mail address*: eman.eshrah01@fvtm.bu.edu.eg

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of the camel nose, in order to elucidate the proboscideal features in this species.

## Camel nose may be a sort of vestibular proboscis

The anatomical structure of the dromedarian nose is typically that of the proboscideal varieties, particularly the vestibular proboscis. Camel nose like any other proboscideal organs can work as a muscular hydrostat, which formed as a result of the reduction of bony and cartilaginous skeleton, coupled with the enlarged musculature and the nasolabial fusion. Such muscular hydrostat can dynamically regulate the nasal air flow, allowing for collection of the inspired particulate and thus cleansing of the inspired air, which is a coordinated adaptation to the dusty environment (Clifford and Witmer, 2004; Eshra and Badawy, 2014). In adverse climatic condition, such as sandstorm, it can allow for complete closure of the nostrils (Eshra and Badawy, 2014).

## The proboscis-like features of the camel nose

Proboscideal noses are diverse organs, which can simply be categorized into vestibular proboscis, and maxillolabial proboscis. The latter is a mobile elongation of the rostral end of the nose, as in swine, and peccaries (Tayassuidae) (Clifford, 2003). The vestibular proboscis is characterized by an expansion of the nasal vestibule with fleshy nostrils that set close to the upper lip (Clifford, 2003; Cliffordand Witmer, 2004). Such vestibular proboscis is responsible for the typically enlarged appearance of the nose in saiga, dik-dik and moose.

For the first while, the external appearance of the camel nose is close to that of the moose (Fig. 1). In addition to these external similarities, there are many common anatomical features shared with moose, as well as the other vestibular proboscis bearing mammals. These include reduced nasal bone, and maxilla forms by a large portion of the bony nostrils in camel (Smuts and Bezuidenhout, 1987; Yahaya *et al*., 2014; Allali *et al*., 2017), in moose and saiga (Clifford, 2003;Clifford and Witmer, 2004), and in dik-dik (Frey and Hofmann, 1997).The mystacial pad was lacking, while the nasal plane (rhinarium) is reduced into a small area (Fig.1), which continues with the median upper lip cleft in camel (Eshrah, 2017), andin moose (Clifford, 2003).The presence of special sacs or recesses, which communicate internally with the nasal vestibule in camel (Arnautovicand Abdalla, 1969, Smuts and Bezuidenhout, 1987, Metwally*et al*., 2019; Eshrah, 2019), and in saiga (Clifford, 2003). In camel, also the nasolacrimal duct opens in the vicinity of the vestibular recess (Eshrah, 2019), while the vomeronasal organ is quite larger and distinct (Badawi and Fath- El Bab, 1974), which is similar to the information reported in the proboscis bearing animals (Clifford, 2003; Clifford and Witmer, 2004). The nasal vestibule dominates the rostral third of nasal cavity, while the nasal conchae were situated more caudally (Fig.2). Similarly, an inclination of the ventral nasal conchae has been observed in camel (Eshrah, 2011; Metwally *et al*., 2019), in moose and saiga (Clifford, 2003; Clifford and Witmer, 2004). The nasal meatuses are large in camel (Fig.2) (Alsafy *et al*., 2014; Metwally *et al*., 2019), in moose (Clifford and Witmer, 2004), and in Taiper (Witmer *et al*., 1999).

Some recent studies revealed other unique anatomical structures, which may be attributed to the presence of proboscis in camel. Such unique structures including, peculiar serpentine duct in the upper lip (Eshra and El-Kamar, 2020), unique sensory island or a patch on the vestibular part of the nasal septum (Abo-Ahmed *et al*., 2021; Ahmed *et al*., 2021). To sum up, at least there are fifteen proboscideal features of the camel nasal anatomy, which were reported in the available literatures (Table 1).

Table 1. The Proboscideal features of the camel nose revisited.

| Proboscideal features of the camel nose | Cited reports |
|---|---|
| Fleshy medial and lateral nasal wings, which are in close opposition to each other. | Badawi and Fath El-Bab (1974)<br>Eshra and Badawy (2014)<br>Metwally *et al*. (2019) |
| Nostrils sag over the upper lip. | Eshra and Badawy (2014) |
| The nostrils and the rostral part of nasal septum are mostly formed of muscles. | Badawi and Fath El-Bab (1974)<br>Eshrah (2011)<br>Eshra and Badawy (2014)<br>Metwally *et al*. (2019) |
| Nasal plane (rhinarium) reduced into a tiny patch that continued with the labial cleft. | Eshrah (2017) |
| Nasaolabial fusion and highly mobile nostrils and upper lip | Eshra and Badawy (2014) |
| Enlarged nasal vestibule | Eshra and Badawy (2014)<br>Metwally *et al*. (2019) |
| Presence of the lateral nasal diverticulum | Arnautovic and Abdalla (1969)<br>Eshrah (2011)<br>Metwally *et al*. (2019)<br>Eshrah (2019) |
| Ostieum of nasaolacrimal duct | Metwally *et al*. (2019)<br>Eshrah (2019) |
| Remarkably large vomronasal organ | Badawi and Fath El-Bab (1974)<br>Eshrah (2011) |
| Reduced nasal bone<br>Wide bony naris | Smuts and Bezuidenhout (1987)<br>Yahaya *et al*. (2014)<br>Allali *et al*. (2017) |
| Reduced cartilaginous skeleton<br>The nasal conchae were retracted caudally<br>The ventral nasal concha was large and inclined | Eshrah (2011)<br>Metwally *et al*. (2019) |
| Large nasal meatuses | Alsafy *et al*. (2014)<br>Metwally *et al*. (2019) |

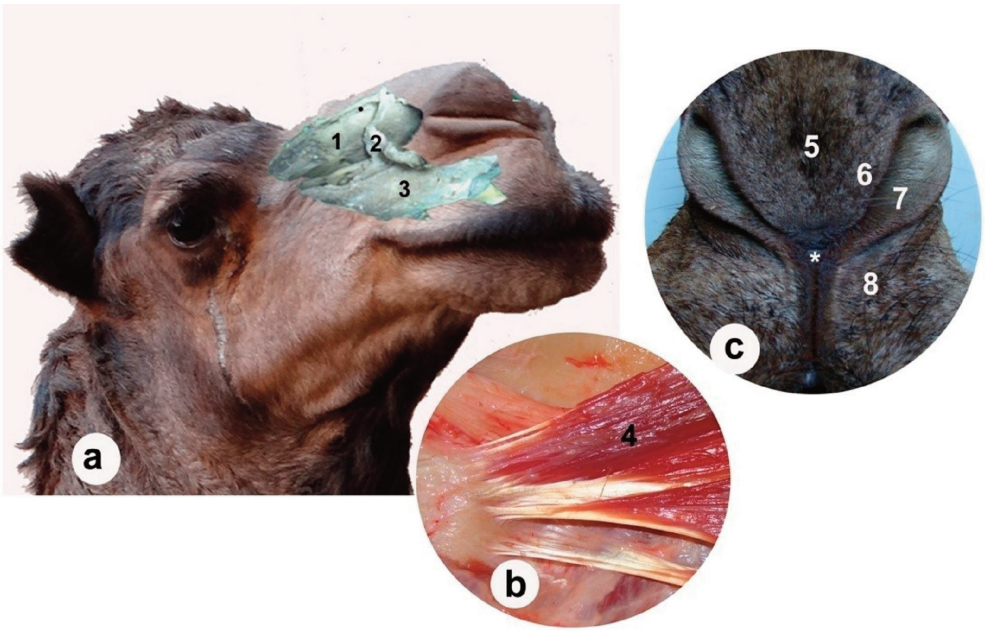


Fig. 1. A photograph of the external appearance and the musculature of the camel nose, showing the essential features attributed to the proboscis: a: nasal septum (1), reduced nasal cartilaginous set (2), maxillary bone (3); b: the maxilolabial group, which is a group of specialized muscles, help narial closure (4); c: The enlarged dorsal part of the nostrils is fleshy and flaccid, typical to those of vestibular proboscis (5), nostrils medial (6) and lateral wings (7) are in close opposition to each other, while the two nostrils are widely separated and sagged over the upper lip. The rhinarium (marked with asterisks) is reduced to a tiny central patch between the edges of the philtrum at the upper lip. The tactile hair (8) is distributed all over the edges of the upper lip, without forming a mystacial pad.

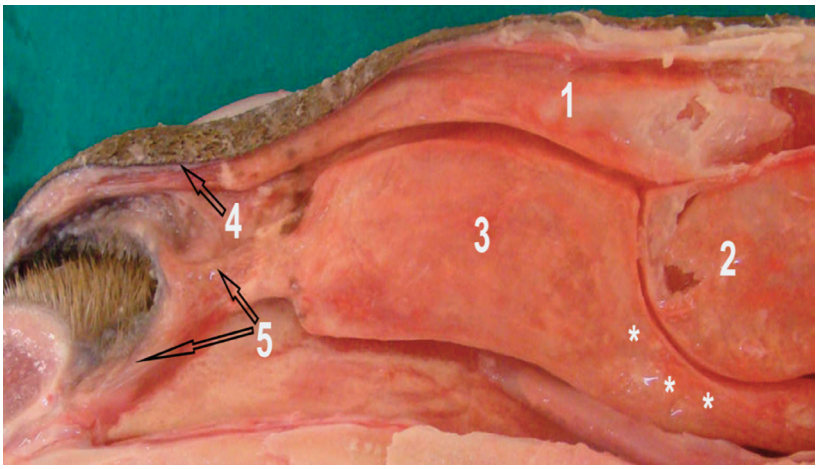


Fig. 2. A photograph of the sagittal section of the camel nasal cavity, showing the essential internal transformations typical of proboscideal nose: Note; the nasal conchae including, the dorsal (1), middle (2), and ventral nasal conchae (3) were retracted to the caudal two thirds, whereas, the ventral nasal concha (3) inclined ventrolatrally (marked by asterisks). Note; the large straight fold (4), and basal fold (5).

All the above-mentioned observations demonstrated that the dromedarian nose has remarkable feature of interest, which may be interpreted as a vestibular proboscis. Consequently, the different components of the camel nose, was discussed here in order to elucidate this hypothesis.

## Osseocartilaginous skeleton

In camel, the nasal bone is reduced (Table 1), and small in comparison with other domestic animals (Smuts and Bezuidenhout, 1987; Yahaya *et al*., 2014; Allali *et al*., 2017). Consequently, the bony aperture of the nasal cavity (i.e. bony naris) is wide and bounded with the lateral round edges of the maxillary bones (Yahaya *et al*., 2014; Allali *et al*., 2017). The nasal cartilages were also reduced (Fig.1), except the dorsal lateral nasal cartilage, which expanded to the whole length of the nasal cavity (Badawi and Fath- El Bab, 1974; Eshrah, 2011; Metwally *et al*, 2019). These also furnish a pulley-like attachment with the levator muscle of the upper lip (Eshra and Badawy, 2014). This osseocartilaginous architecture provides vast attachment site for the musculature controlling the aperture of the nostrils as well as the upper lip mobility. Typically, these attributes of narial architecture have been observed in diverse sorts of vestibular proboscis (Clifford, 2003; Clifford and Witmer, 2004; Witmer *et al*., 1999).

## Muscles of the nose

In camel, the boundaries of the nostrils are mostly muscular (Table 1), including the medial boundary, which formed by the rostral part of nasal septum (Badawiand Fath- El Bab, 1974; Metwally *et al*., 2019). Similarly, the vestibular proboscis has fleshy nostrils, but the nasal septum is largely membranous with a large patch of cavernous tissue (Clifford, 2003).

In camel, all the facial muscles around the nostrils are arranged in four layers, and interestingly, inserted without

tendineous attachment into the orbicularis oris (Eshra and Badawy, 2014). This enables the muscles of the nostrils and the upper lip to work synchronously and provide high mobility for the animal rostrum as a whole. Similar muscular arrangement was reported in the proboscideal animals, except for the muscular attachment, which were almost tendinous (Clifford, 2003).

The most conspicuous feature present in both camel and the proboscideal nose is a specialized group of muscles, known as the maxillolabial group in camel (Fig. 1) (Eshra and Badawy, 2014); in dik-dik (Saber, 1987), in saiga and moose (Clifford and Witmer, 2004). The maxillolabial group and the lateralis nasi act together to compress the nasal cavity and control dilatation of the nostrils, these greatly allow modification of air flowing through the nasal cavity It has also been proposed in camel that this group of muscles may play a role in narial closure, which is an essential feature of the vestibular proboscis (Eshra and Badawy, 2014).

## Nasal conchae and mucosal folds

Enlarged nasal vestibule coupled with rearrangement of nasal conchae, are major transformation of the nasal internal anatomy, which usually correlates to the presence of the vestibular proboscis (Witmer *et al*., 1999). In such organs, the nasal vestibule is greatly enlarged; displacing the nasal conchae caudally within the nasal cavity and as a result the nasal meatuses are wider than in the other animals. Consequently, the conchae are tightly packed, the basal folds are repositioned, and the ventral nasal concha appears inclined, as it rotates such that the attachment of concha changes from ventral to lateral as it extends caudally. Such anatomical transformations, which comprise of the enlarged nasal vestibule, the large meatuses, the retracted conchae, the inclined ventral nasal conchae, and the repositioned basal folds (Fig. 2), were all observed in camel (Metwally *et al*., 2019).

## Conclusion

The nose of the dromedary is unique from that of the other ruminant species. It differs both in the gross anatomy of the snout and the internal organization of the nasal cavity. Whereas, the structure of the dromedarian nose is consistent with a vestibular proboscis, which is comparably smaller than those of other proboscis-bearing species.

## Conflict of interest

The authors declared that they have no conflict of interest.

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