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Peculiar Labial Duct in the Camel Philtrum: Structure and Feasible Functions

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ABSTRACT

The philtrum is well known as a median groove within the upper lip of mammalian species. However, a peculiar serpentine duct was identified within the mucosal surface of the camel philtrum. To the best of the author's knowledge, the available literature did not mention any information regarding the presence of a complete duct in such location. For these, this study was aimed to reveal the gross and microscopic structure as well as to discuss the possible functions of this labial duct in dromedary. Twenty snouts from 20 camel heads were used. The labial duct had unique morphological and microscopic structure. It was a median highly tortuous duct with proximal and distal segments connected to each other through a capillary portion. The latter revealed only at the microscopic level. The duct had two entrances, the proximal and distal papillae. Importantly, the microscopic studies revealed that it also had an olfactory portion. In conclusion, the labial duct in camels is a peculiar anatomical structure, which may function as an organ of alarm.

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Introduction

The philtrum is a median groove in the upper lip of domestic animals (Nickel *et al.*, 1979). It usually found in animals that possessed a rhinarium or a nasal plane (NP) such as carnivores and small ruminants (Nickel *et al.*, 1979; Evans and Christensen, 1979). The nasal plane is a wet glabrous skin area, which covers the medial wings of the nostrils (Nickel *et al.*, 1979). The philtrum in such species is deep and sometimes extends to the nostrils. On the other hand, it's shallow or absent in animals that lack NP, as equine (Nickel *et al.*, 1979). This anatomical association is also indicating functional correlations between the philtrum and the NP (Hillenius and Rehorek, 2005). The philtrum proposed to drain the odoront molecules that dissolved in the fluid covering the NP to reach the incisive papillae and then into the nasopalatine ducts (Wöhrmann-Repenning and Bergmann, 2001). While the nasopalatine ducts or incisive ducts are the oro-nasal passage of the vomeronasal duct system (VNO), the philtrum thereby is considered the communication canal between the NP and the VNO (Hillenius and Rehorek, 2005; Eshrah, 2019).

In contrast to other domestic animals, camels have a different oro-nasal arrangement. Much of the muscular tissue was present anteriorly, where the nasal and labial musculature, forming together a highly movable syncytium like that found in propocideal nose (Eshra and Badawy, 2014, Metwally *et al.*, 2019). The nasal plane is formed of a very small area that covers only the philtrum (Eshrah, 2017). Thus, in camels the NP is the philtrum itself, which located entirely within the highly movable upper lip.

Although the nasopalatine duct ends blindly in the hard palate of camels (Karimi *et al.*, 2014), the functional correlations between NP and VNO are still the same as those proposed in other animals. The camel NP may help deliver dissolved odorants into the nasal opening of VNO, and thus may functionally substitute the lack of VNO oral communication in this species (Eshrah, 2019).

Interestingly, the duct documented in this study was found entirely within the philtrum. To the best of our knowledge, the available literature did not declare any information regarding the presence of a complete duct in such location in any mammalian species. Therefore, the aim of the present study was to describe in detail the gross and microscopic anatomy and to discuss the possible functions.

Materials and methods

Samples

This study was performed in accordance with the ethical guidelines approved by the Institutional Animal Care and Use

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Committee of the Faculty of Veterinary Medicine, Benha University, Egypt. The study was conducted on 20 snouts from 20 camel heads. The camels (Camelus dromedarius) were apparently healthy mature males 3–6 years old. All specimens were obtained immediately after slaughter from Toukh and Qalioube abattoir, Egypt. Congenital or acquired abnormalities of the head or the upper lip were considered exclusion criteria. Fifteen specimens were used for the anatomical studies, while the other five samples were used for the histological study. One sample was dried and then transected to demonstrate the course of the labial duct.

Histology

Histological specimens were obtained immediately after slaughter, transected to obtain cross, sagittal and oblique sections. The tissue specimens were fixed in 10% neutral formalin, dehydrated in ascending grades of alcohol (70-100), cleared in xylene, and embedded in paraffin. Three µm sections were mounted and stained with hematoxylin and eosin (H&E) (Bancroft and Stevens, 1997).

Results

Gross anatomy

The philtrum is a deep median groove in the upper lip of camels (Fig.1a). It had two surfaces, the external (cutaneous) and internal (mucosal) surfaces, and two borders, the proximal (nasal) and distal (labial) border. The inner surface was facing the oral vestibule, covered by the labial mucous membrane and attached to the gum by a distinct frenulum (Figs. 1b, c).

The labial duct was coursed within the mucosal (internal) surface of the philtrum. It started distally at about 1-1.5 cm from the distal border of the philtrum, where its distal end, the distal papilla was located (Figs. 1b, c). The proximal papilla formed the upper end of the labial duct. The distal papilla was often very small unnoticed papilla; however, it was sizable and prominent in some camels (Figs. 1b, c). Whereas, the proximal papilla was completely veiled by the frenulum in all specimens, and getting noticed only during dissection (Fig. 1d). Each papilla was related laterally to the labial glands, which possessed several papillated (raised) secretory orifices (Figs. 1 b, c; 2 a, b).

An imaginary line of 4 cm in length connected the two papillae (Fig. 2a). The proximal papilla often obstructed with food particles (Fig. 2a). In some specimens, the papillary opening was divided by a thin skin flap into two diverticula (Fig. 2b).

Notably, the labial duct cannot be probed except for the first initial centimeter. The probe usually stopped within this initial segment as if it was obstructed but curiously the duct lumen appeared again in the next centimeter until it ended proximally in the proximal papilla (Figs. 3 a-d). Accordingly,

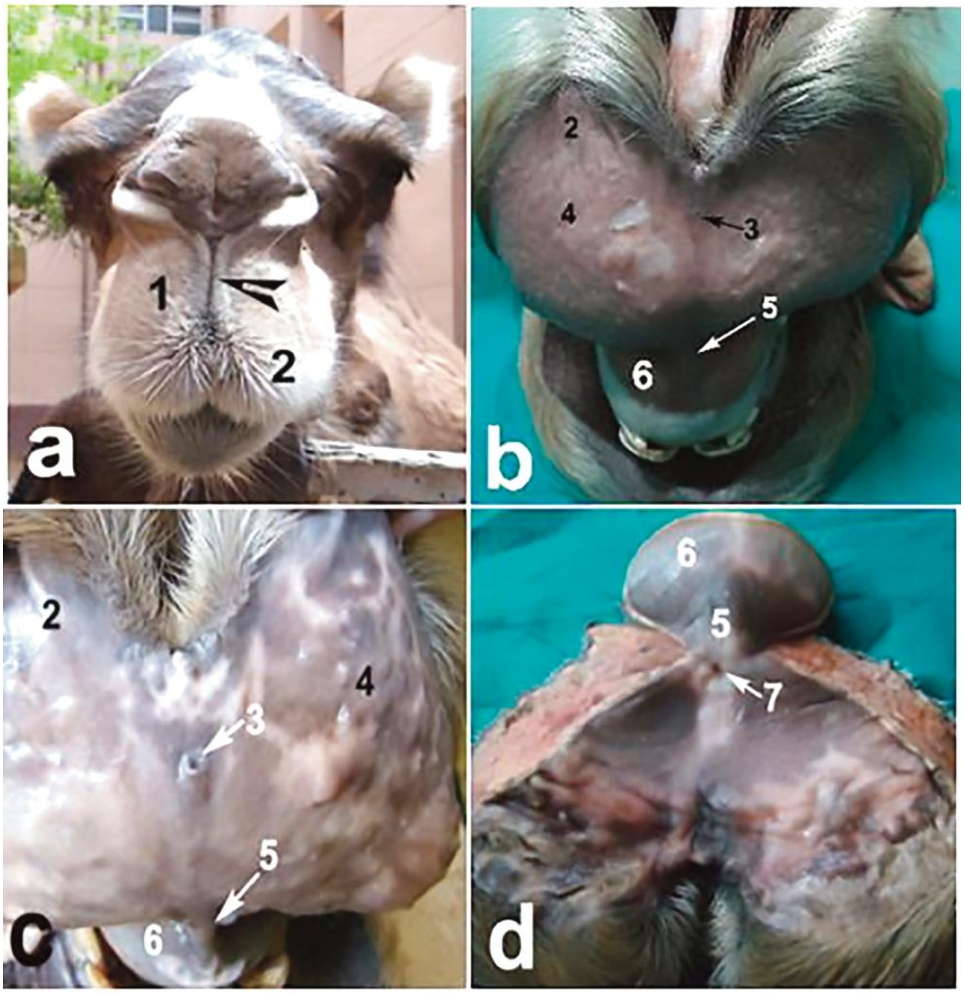

Fig.1. The camel snout in a living animal (a) dissected specimens showing the inner (mucosal) surface of upper lip (b, c, d): (1) external (cutaneous) surface of upper lip, (2) finger-like process of the upper lip, philtrum (black arrowhead), (3) distal papilla, (4) labial glands, notice papillated glandular orifices, (5) frenulum attached the philtrum to the gum (6) the dental pad (gum pad), (7) proximal papilla.

the duct can be divided into three parts, which including, the distal (initial) duct segment, proximal duct segment, and a capillary (microscopic) portion in-between. The initial part of each segment started as an ampullary portion, which continued as a much smaller duct. The latter was abruptly narrowed to the microscopic level when it met the capillary portion.

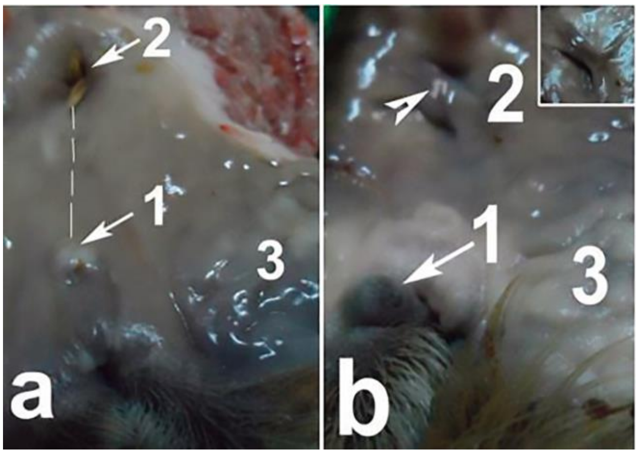

Fig. 2. The inner surface of upper lip in dromedary, showing: (1) the distal papilla, (2) the proximal papilla, containing hay (straw) particles (a), and in some cases was divided by a skin flap (b, in the inset), notice the imaginary line between two papillae, which is 4 cm in length, (3) labial glands.

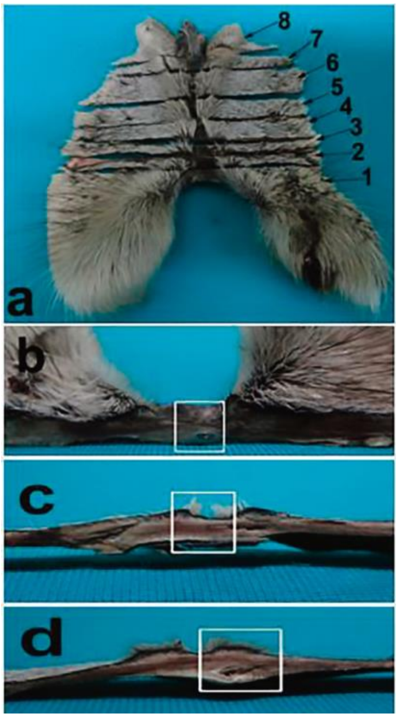

Fig. 3. A dried sample of the camel upper lip sectioned into 8 cross sections (a), notice the ampullary duct portions of the distal (b) and proximal (d) duct segments, which are corresponding to section 1, 7 respectively, while in the section 3, the duct portion suddenly disappeared from view (c).

Histology

The proximal and distal papillae were two layered keratinized structures, formed of the epidermis and dermis. The basal layer of epidermis was densely infiltrated with melanin pigments. The dermal papilla was radially arranged, forming a distinct rosette shaped pattern (Fig. 4). Continuing with the papillary lining, the ampullary portions were also formed of keratinized skin, but with a wider lumen and shallower dermal papillae (Fig. 5). Furthermore, the lining epithelium become none keratinized stratified squamous epithelium (Figs. 6 a-c). The labial duct was highly tortuous, coursed median but in various planes. Cross, longitudinal and oblique ductile portions can be observed within the same histological sections (Figs. 6 a-c). The capillary portion lined by flat endothelial-like cells, which supported by dense fibrous tissue (Figs. 6 a-c).

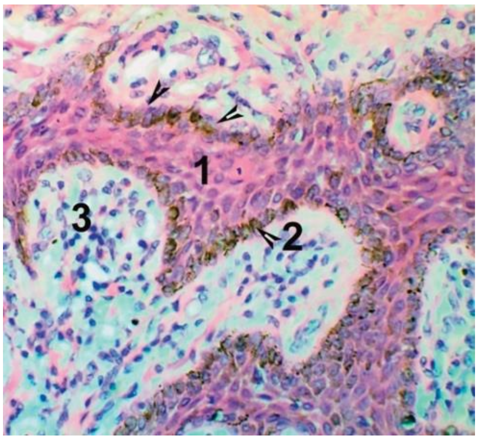

Fig. 4. A cross histological section in the distal papilla H&E, X 400, (1) epidermis (2) basal layer, very rich in melanin pigments (black arrowheads) (3) dermal papillae, notice the rosette shape arrangement.

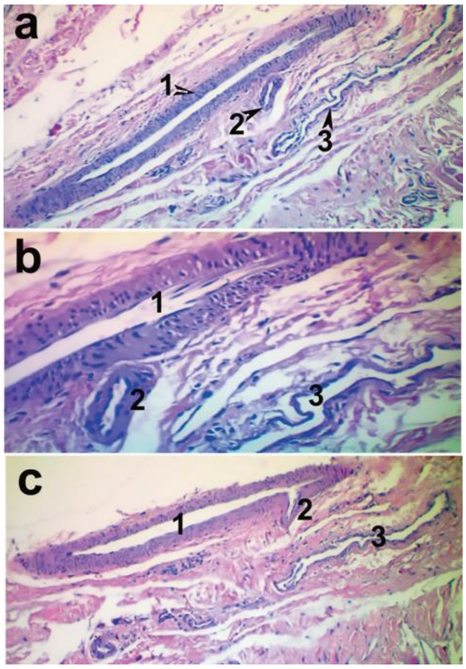

Fig. 5. A cross histological section in the ampullary portion (proximal duct segment) H&E, X 100, (1) epidermis, stratified squamous epithelium with distinct keratin layer (black arrowheads) (2) wide lumen, containing some debri (3) dermis.

An olfactory portion was revealed within the proximal segment (Figs. 7 a-c). The duct appeared triangular with rounded angles (Fig. 7 a). It was lined with typically pseudostratified olfactory epithelium (Figs. 7 a-c). The supporting cells, the sensory bipolar cells and the basal cells were clearly demonstrated (Figs. 7 b-c). There were two types of basal cells, the globose and horizontal basal cells (Figs. 7 b-c). The lamina propria was highly cellular (Figs. 7 b-c). The incidence of these cells varied regionally within the duct epithelium (Figs. 7 b-c). Some regions had multiple layers (4-5) of bipolar cell bodies (Fig. 8 a), while others had only two rows (Fig. 8 b). In addition, two types of supporting cells were also recognized (Figs. 8 a, b).

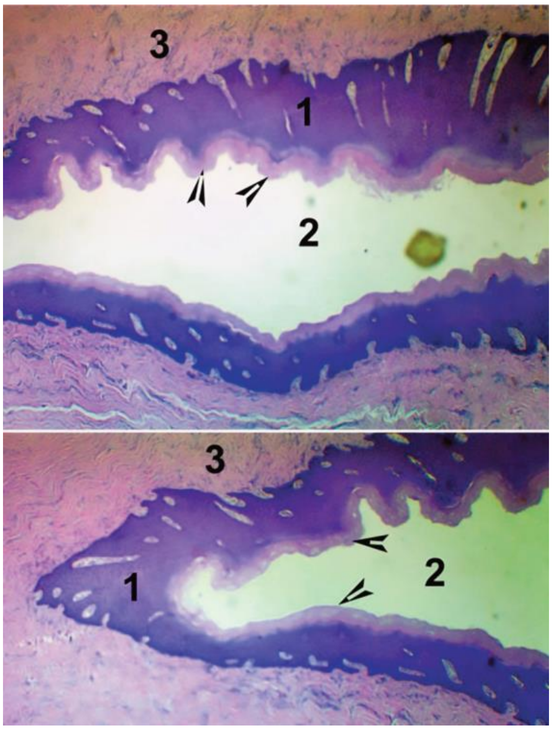

Fig. 6. A sagittal histological section in the distal duct segment H&E, a, c, X 100, b, X 400 (1), (2) duct portions lined with non-keratinized stratified squamous epithelium (3) the capillary (microscopic) portion, notice how the parts 1 and 2 unite together in a tortuous course.

Discussion

The present study has been revealed a novel anatomical structure, which is the labial duct in dromedaries. This duct was of unique location, morphological features and microscopic structure. It was a highly tortuous duct, which formed of two segments connected through a capillary portion that cannot be seen with the naked eye. The microscopic study confirmed the presence of this capillary portion. Moreover, within the proximal duct segment an olfactory segment, which has an extent of only a few micrometers, was also observed. Besides its serpentine course, it has two entrances, namely, the proximal and distal papillae. Theses entrances were laterally located to the openings of the labial glands. Such morphological features may imply certain functions. For these, we try to discuss here the duct structure in relation to the feasible functions.

Notably, the presence of olfactory epithelium within the duct undoubtedly indicates functions related to olfaction. This raises the question; what kind of olfactory cues require detection out of the nasal cavity? Information about the environment is readily available in the form of two types of olfactory cues, volatile and non-volatile (Mathis and Crane, 2017). The volatile odors, as their name implies are those carried by air. Thus, they can enter the nasal cavity passively with inspired air, or actively via sniffing action (Wood, 2012). While the non-volatile odors (NVO) are usually “heavier” than the air itself, so they cannot be carried by the inspired air either passively

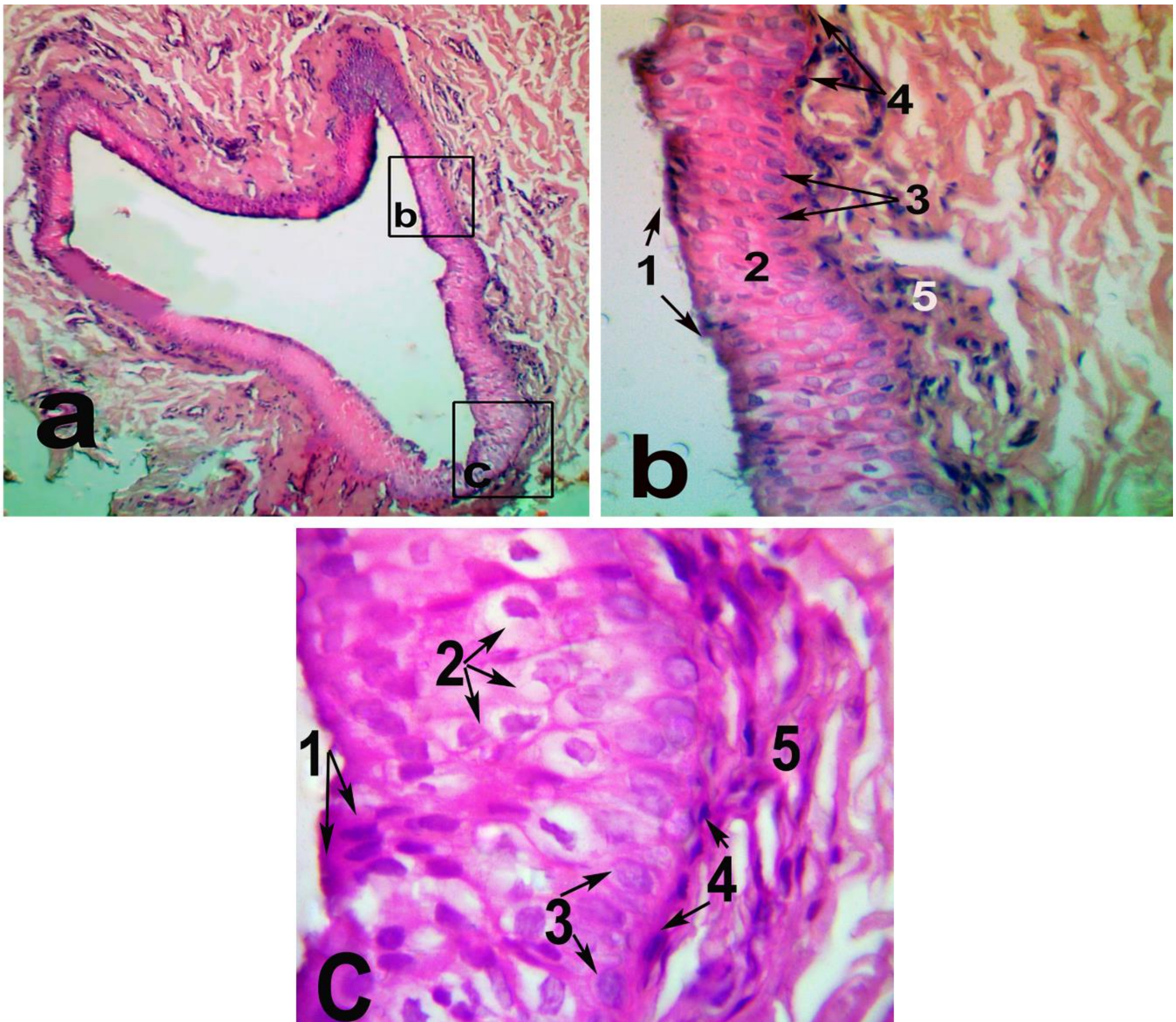

Fig. 7. The olfactory portion of the labial duct in dromedary (a) the whole duct H&E, X 100 (b,c) regional cellular arrangement within the duct H&E, x 400 (b), x1000 (c). (1) supporting cells (2) bipolar cells (3) the globose basal cells (4) the horizontal basal cells, (5) highly cellular lamina propria.

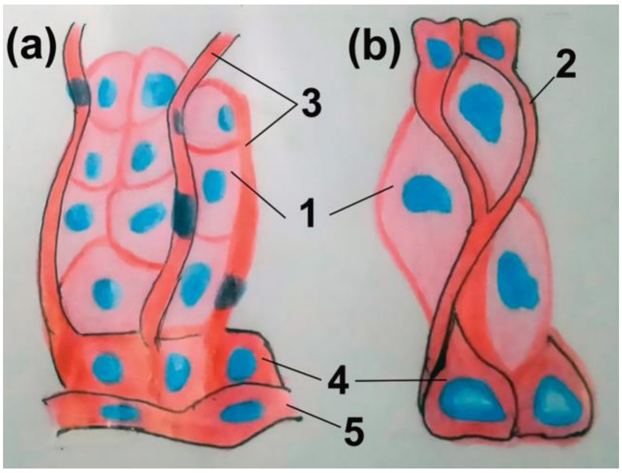

Fig. 8. A schematic representation showing the cellular arrangement within the olfactory portion (a, b), notice, some regions has multiple bipolar cells (1) while, the others have only two, these bipolar cell bodies held together by the supporting cells (2,3), notice the nucleus of supporting cells either found at the top (2) or in the middle (3). Also, there are two types of basal cells, the globose basal cells (4) and the horizontal basal cells (5).

or actively. Instead they carried in a liquid phase solution, such as sweat, urine, genital secretions, scent gland secretions etc. (Vitt and Cladwell, 2009). These NVO molecules were essential for the animal behavior and communications, as well as animal reproduction (Wysocki *et al*., 1982; Shipley *et al*., 2004). The organ that responds to such molecules is the vomeronasal organ. Since, the NVO are carried in a fluid medium, they require carrying and then transferring into the openings of VNO. The tongue is responsible for carrying and transferring The NVO into the incisive papilla, which is the oral opening of the VNO duct system (Døving and Trotier, 1998). This perhaps may rationalize why some animals have an oral communication with VNO.

However, the unexpectedly highly tortuous course of the labial duct in dromedaries suggests the sampling of distinct types of odors, rather than those detected by the VNO duct system or the main olfactory epithelium. On the other hand, the rostral location of the labial duct entrances and the food particles that found within the duct lumen indicate a function related to food sampling. In other words, it may be involved in the early detection of alarm cues in the animal food. In the desert environment, there are poisonous plants much more than the edible types. The labial duct possibly works as an organ of alarm that "sample" plant particles and up the afferent nerve notify the cortex either the sample is normal or harmful. In support of this, the existence of the labial duct itself in such location, i.e. within the lip facing the oral vestibule, this would permit probing of food before it enters the mouth. The presence of an alternative wide and capillary ductile portion, together with the labial muscles may work as a "suction pump". This pump proposed to help the entry of such olfactory cues into the duct openings.

The labial glands that located just lateral to the duct papillae may provide the secretion required for trapping odorants into the labial duct. While the lacrimal secretions are suitable for trapping the VNO odorants (Rossie and Smith, 2007), the labial glands as any salivary gland are well suited for the treatment of food particles. Supporting this speculation is that the openings of the labial glands are raised like tiny papillae. Such openings are built for getting their secretion areolized as a fine spray in the air (Widdicombe and Wine, 2015). This would allow the secretions to bind with olfactory cues while it still in the oral vestibule. Then, the trapped molecules can passively access the openings of the duct papillae because they are in close proximity of the glandular openings. An active entry for these molecules is also possible via the proposed suction force of ampullary portions and labial muscles.

To sum up, on the basis of macro and micro-structure the feasible mechanism of the labial duct is as follows: the duct may able to locate odorants molecules associated with food particles before it enters the mouth. While the food (plant) grasped by the upper lip and still in the oral vestibule, the labial gland secretions trap the olfactory cues. The dissolved cues can enter into the duct either passively or actively as proposed above. The tortuous course may help the filtration of such cues within the duct until they reach the olfactory portion. The olfactory bipolar cells within the duct detect alarm substances and notify the cortex via their afferent nerves.

Finally, similar to the olfactory organ of Gruenberg (Storan and Key, 2006), the olfactory portion of the labial duct is a minor island of unusual rostral location. For this it would not be seen with routine histological sectioning of the camel nasal cavity. In this study, we randomly found this segment, only in one specimen. This may be because the duct was highly tortuous and this olfactory segment was of few microns. Therefore, further investigations are required to pinpoint the location and extension of the olfactory portion of this duct and to define the nerve supply.

Conclusion

The labial duct in dromedary is a novel anatomical structure. The rostral location, the anatomical and histological structure, indicate that it possibly works as an organ of alarm. This can be used as a base for further investigations, particularly those concerning the neuroanatomy comparative and developmental anatomy of this duct system.

Conflict of interest

No conflict of interest has been declared by the authors.

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