



## Gross, histological and electron microscopical features of the hard palate mucosa in the one-humped camel (*Camelus dromedarius*)

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### Abstract

The purpose of the current work is to study mucosa of the camel hard palate morphology by gross anatomy, morphometric analysis in addition to light and scanning electron microscopy (SEM). Ten heads of freshly slaughtered camels were collected from Zagazig abattoir. The selected camels were in good general condition, their ages were ranged around three to five years. Anatomically, the hard palate was elongated and it could be divided into a narrow rostral part and a caudal wide part with about 13-14 transverse palatine ridges. The dental pad was a crescentic thick plate at the rostral end of hard palate. The incisive papilla is triangular prominence situated behind the dental pad in the median plane and is surrounded by shallow groove, microscopically, the mucosa of hard palate consisted of a keratinized squamous epithelium. The submucosa comprised from vascularized collagenous connective tissues run in various directions. The soft caudal part of the hard palate is distinguished by lobulated serous acini and it was rich in adipocytes. Scanning electron microscopy demonstrated the stratification of the epithelium; with excessive desquamation and sloughing of the epithelial cells. By high magnification, the microplacae system was inform of irregular surface separated by septae.

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### Introduction

The dromedary camels (one-humped camels) are important livestock animal and there are various studies including many aspects of sciences (1-4). There are a lot of literatures about different anatomical structures of camel (5-16). The camel has two species, one humped camel found in Africa, Arabia, Iran, Afghanistan and India and the two-humped camel found in Central Asia, reaching up to Mongolia and Western part of China (17). The dromedary camels represented about 94% of the population of camels which distributed all over the world, commonly in the Middle East and the Northern Africa (18). The palate forms the roof of the oral cavity, and its rostral segment is called the hard palate (Palatum durum). The hard palate constitutes a part of the upper digestive system and play an important role in swallowing the ingesta by transverse ridges on the external surface. In harsh and desert regions, the animals are

faced extreme environmental conditions. Unlike small animals, the one humped camel (*Camelus dromedaries*) which is continuously exposed for lack of water, heat, solar radiation, drought and scarcity of food, various adaptive strategies in order to cope with this specific and drastic environment. In spite of these arid conditions, the dromedary camel is also capable of maintaining important productions such as meat, milk, hair and wool (19). So, the dromedary camel is one of the most important models for studying adaptation to extreme environments. The hard palate is a valuable portion of the oral cavity and it has a unique role during food prehension and mastication as it forms a hard surface opposite to the tongue, so the tongue can press food against it (20). The hard palate is consisted of the incisive papilla, palatine ridges, and palatine raphe and it could be divided into a narrow rostral part and a wide caudal part (21,22). The literatures on the anatomical peculiarities of the hard palate of the camel is scanty, also the available data

about the hard palate morphology in other ruminants in veterinary anatomy textbooks is few (23-26).

Furthermore, there is no study explained the detailed morphology of the hard palate in camel. Consequently, the aim of the present work was to investigate the mucosa of hard palate using gross anatomy, morphometric, histological structure and scanning electron microscopy (SEM). The data in the current study would be useful in explaining adaptation of the hard palate in feeding and in comparison, morphology with other ruminants.

## **Materials and methods**

### **Ethical approve**

The handling of animals in this study was followed the guidelines of the Institutional Animal Care and the Research Ethics Committee of the Zagazig University, with an ethical approval number of (ZU-IACUC/2/F /194/2022).

### **Sample collection**

The specimens for the present work included ten heads of freshly slaughtered camels (*Camelus dromedarius*). The specimens were collected from Zagazig abattoir. The selected camels were in good general condition, their ages were ranged around three to five years.

### **Bones preparation**

A head of adult camel was obtained to describe the external morphology. The bony preparations were carried out by maceration method (27).

### **Gross anatomical examination**

To expose the hard palate, the upper and lower jaws were separated through the temporo-mandibular articulation. Five heads were injected via the common carotid artery with 10% buffered neutral formalin solution for at least four weeks to be used in anatomical investigation and morphometry.

### **Morphometric measurements**

The measurements of camel hard palate include the lengths and widths of different parts of the hard palate using Vernier caliper. Moreover, the dimensions of the dental pad and incisive papilla were recorded. Data were expressed as Mean  $\pm$  SD.

### **Histological examination**

For histological observations, the hard palate was extracted from freshly slaughtered camels, the mucosa of the hard palate was extracted carefully by sharp scalpel from rostral, middle and caudal parts of the hard palate. The specimens were fixed in 10% buffered neutral formalin, 5-6 microns thick sections were cut. The sections were stained with the Harris's hematoxylin and eosin (HE) stain for studying the general histological structures (28).

### **Scanning electron microscopy**

The hard palate specimens were fixed immediately after slaughter in 2.5% of glutaraldehyde solution for 48 h. After that washed by 0.1 M phosphate buffer solution twice. The tissues were kept in a 1% of osmium tetroxide solution for 1 h, then handled by acetone sequences and dehydrated by critical point drying (CPD). The specimens were plated by Gold-Palladium and studied by a scanning electron microscope at various magnifications. The specimens were examined with JSM-6510LV scanning electron microscope (JEOL CO., USA) at an accelerating voltage of 20, 30 kV. This portion of current study was performed at Faculty of Agriculture, Mansoura University (29).

## **Results**

### **Gross anatomy and morphometry**

The hard palate (Palatum durum) constitutes the great part of the roof of the oral cavity. The hard palate has a bony basis consisted of palatine process of incisive, maxillary bones and the horizontal part of palatine bone (Figure 1). The palate forms the roof of the oral cavity, and it consists of hard and soft parts, its rostral segment is called the hard palate (Palatum durum) (Figure 2). The hard palate is osseous palate and the mucosa which covers its oral surface. The hard palate divided into an elongated narrow rostral part and a caudal wide part, which it commenced suddenly at the level of the third premolar tooth with total length 30.11 cm (Figure 3).

It is bounded rostrally and laterally by the upper dental arch and continued laterally with the gums and caudally with the mucous membrane of the soft palate. The rostral part of the upper dental arch is incomplete and it is modified by dental pad. Just behind the dental pad there is a pair of the lateral or corner upper incisor teeth. The upper pair of canine teeth is located by short interval to the incisor teeth, also by somewhat long distance caudal to the canine teeth there are a pair of first pre molar teeth (Figure 4).

The hard palate contained on its elongated long narrow rostral part transverse ridges (rugae palatinae) however, the caudal part is smooth. The palatine ridges pass transversely through the palate and are interrupted in the median plane by the palatine raphae which divided the hard palate into equal parts. These ridges are irregular concave in shape (Figures 3 and 4).

The narrow part was nearly equal in width, it measured about 17.09 cm. While the wide part it commenced abruptly at the level of the third upper premolar tooth, then it gradually increased in width caudally about 7.97 cm (Table 1 and Figure 5). The palatine raphae (Raphe palati): It began as elevated line (as crest like) from the dental pad until the first premolar, the whole length of the hard palate as crest like with 11.40 cm length. At the level of the first premolar the crest transformed to groove. This groove extended from first premolar to the third premolar with 6.80 cm length.

**The dental pad (Pulvinus dentalis)**

The rostral end of hard palate presents a semilunar in shape dental pad serves as a counterpart to upper incisors as a crescentic thick plate. It attached to the body of incisive bone (premaxilla) (Figure 1). The outer concave caudal part of the dental pad attached to upper incisor teeth. The caudal convex inner part of the dental pad was depressed centrally and it was occupied by the incisive papilla. The incisive papilla is triangular prominence situated behind the dental pad in the median plane and is surrounded by shallow groove. The openings of nasopalatine are blind after removal of the incisive papilla (Figure 4 and Table 1).

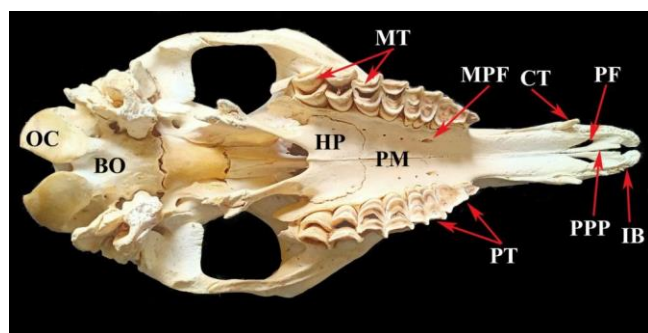


Figure 1: A shows the skull of the camel (ventral view) (IB) Incisive bone, (PPP) Palatine process of premaxilla, (PF) Palatine fissure, (CT) Canine tooth, (MPF) Minor palatine foramen, (PT) Premolar teeth, (MT) Molar teeth, (PM) Palatine process of maxilla, (HP) Horizontal plate of palatine bone, (BO) Basilar part of occipital bone and (OC) occipital condyle.

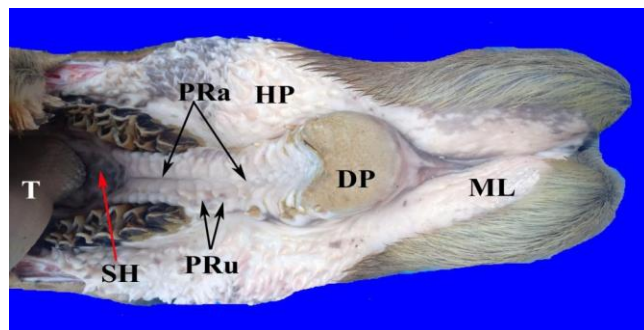


Figure 2: A hard palate within oral cavity shows (ML) Upper lip, (DP) Dental pad, (HP) Buccal papillae, (PRa) Palatine raphae (PRu) Palatine rugae, (SH) Smooth part of hard palate and (T) Tongue.

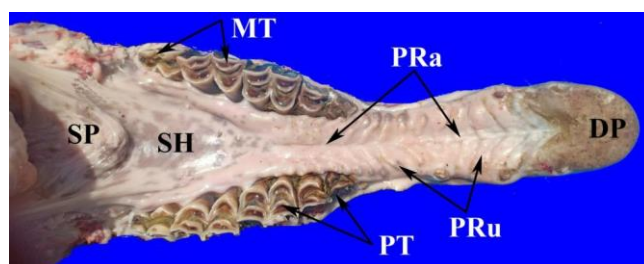


Figure 3: A hard palate shows, (DP) Dental pad, (PRa) Palatine raphae, (PRu) Palatine rugae, (PT) Premolar teeth, (MT) Molar teeth, (SH) Smooth part of hard palate and (SP) Soft palate.

Table 1: The morphometric measurements of camel hard palate

Parameters	N	Minimum	Maximum	Mean	Std. Error	Std. Dev.
Total length (cm)	10	29.70	30.50	30.1100	0.08492	0.26854
Length of Narrow part (cm)	10	16.60	17.50	17.0900	0.09123	0.28848
Length of wide part (cm)	10	12.70	13.50	13.0700	0.08950	0.28304
Width of Narrow part (cm)	10	3.60	4.00	3.8100	0.04583	0.14491
Width of wide part (cm)	10	7.70	8.30	7.9700	0.05972	0.18886
Numbers of ridges	10	13.00	14.00	13.5000	0.16667	0.52705
Length of palatine raphe (ridge) (cm)	10	10.60	11.40	10.9500	0.08596	0.27183
Length of palatine raphe (groove) (cm)	10	6.30	6.80	6.5400	0.05416	0.17127
Length of dental pad (cm)	10	4.50	4.80	4.6700	0.03667	0.11595
Width of dental pad (cm)	10	3.60	3.90	3.7900	0.03145	0.09944
Thickness of dental pad (cm)	10	1.80	2.20	2.0000	0.04714	0.14907
Length of incisive papilla (cm)	10	0.80	1.20	0.9400	0.04269	0.13499
Width of incisive papilla (cm)	10	0.40	0.60	0.5000	0.02582	0.08165
Thickness of incisive papilla (cm)	10	0.30	0.40	0.3450	0.01384	0.04378

**Histological investigations**

The mucosa of incisive papilla consisted of a keratinized stratified squamous epithelium with papillary projections which it formed mainly from keratinocytes. The lamina

propria submucosa comprised from vascularized collagenous connective tissues run in various directions (Figure 6). The dental pad characterized by long rete pegs extended into the underlying collagenous connective tissues.

The collagenous submucosa is well vascularized with some lymph vessels (Figure 7). The mucosa of the palatine ridges composed of a keratinized stratified squamous epithelium containing too many elliptical to ovoid structures having vacuolated keratinocytes. The submucosa of this area is rich in adipose tissues (Figure 8). The soft caudal part of the hard palate is distinguished by lobulated serous acini separated by connective tissues septa rich in adipocytes (Figure 9).

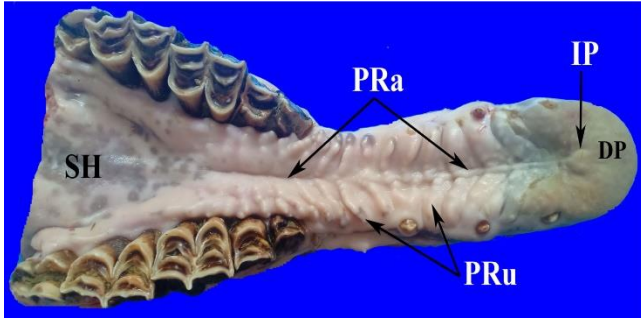


Figure 4: A hard palate with rostral part shows (DP) Dental pad, (IP) Incisive papilla, (PRa) Palatine raphae, (PRu) Palatine rugae and (SH) Smooth part of hard palate

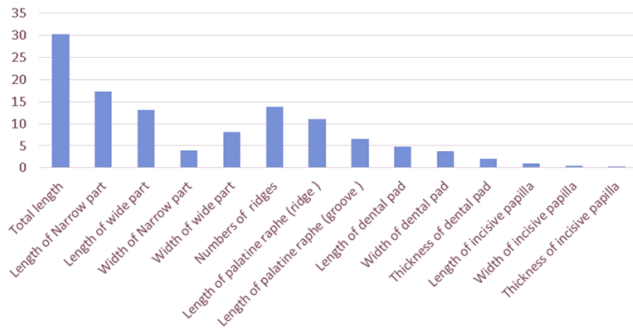


Figure 5: The morphometric measurements of camel hard palate.

### Scanning electron microscopy

Scanning electron microscopy revealed the stratification of the epithelium; the surface of the epithelium was flat and covered by normal and desquamated epithelial and sloughing of the epithelial cells (Figure 10). The oral surface of the hard palate was unequal, it showed many transverse palatine folds and depression. The palatine folds are connected with each other's by longitudinal interconnecting folds (Figure 10). The incisive papilla showed palatine papillae (Figure 11). At higher magnification, the surface of the palatine ridges, dental pad and incisive papilla showed, microplicae system, which it informs of irregular surface separated by septae (Figure 11). By high magnification, microridges of various forms could be seen (Figure 10). The smooth caudal part of the hard palate contained palatine glands opening (Figure 11).

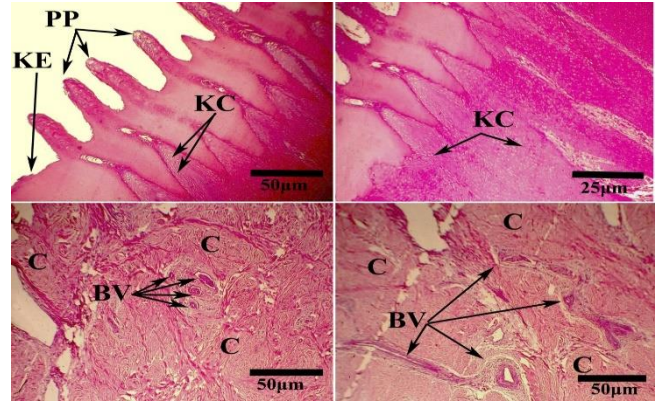


Figure 6: A photomicrograph of incisive papilla showing (PP) Papillary projections, (KE) Keratinized epithelium, (KC) Keratinocytes, (C) Collagenous fibers and (BV) Blood vessels.

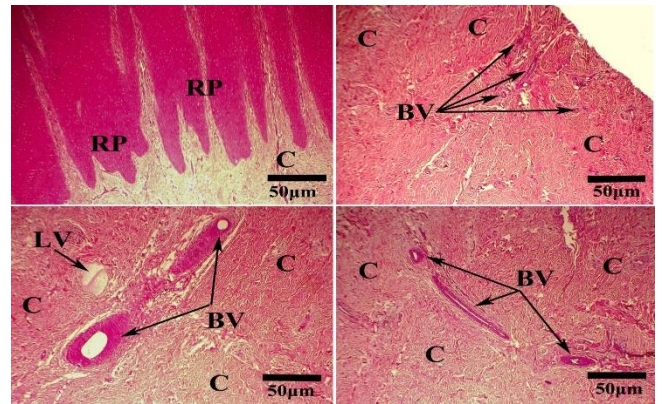


Figure 7: A photomicrograph of dental pad showing (RP) Rete pegs, (C) Collagenous fibers, (BV) Blood vessels and (LV) Lymph vessel.

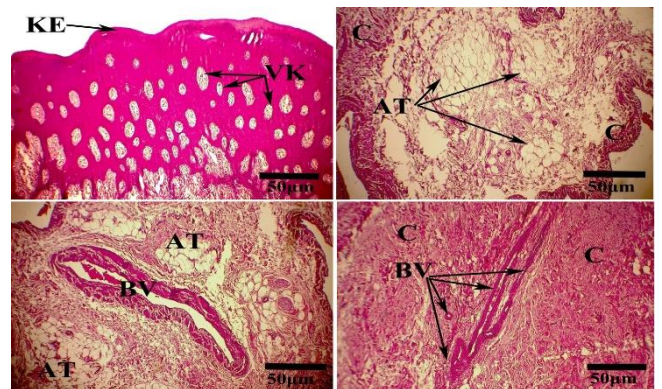


Figure 8: A photomicrograph of dental pad showing KE Keratinized epithelium, (C) Collagenous fibers, (BV) Blood vessels, (AT) Adipose tissues and (VK) Vacuolated cells.

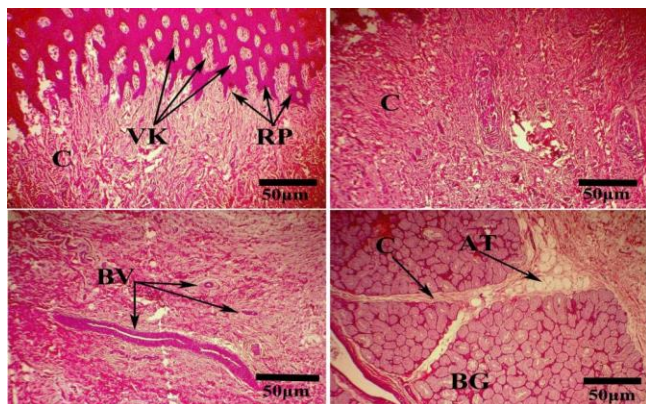


Figure 9: A photomicrograph of dental pad showing (C) Collagenous fibers, (BV) Blood vessels, (AT) Adipose tissue, (VK) Vacuolated cells, (RP) Rete pegs, (AT) Adipose tissues and (BG) Buccal gland.

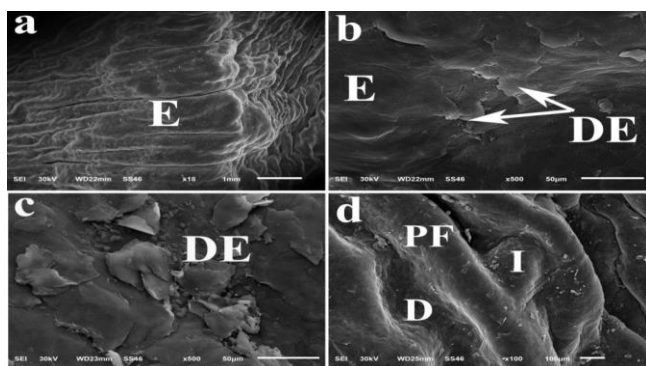


Figure 10: Scanning electron micrographs of camel hard palate a,b,c and d showing: (E) Epithelium, (DE) Desquamated epithelium, (PF) Palatine fold, (D) Depression and (I) Interconnecting fold.

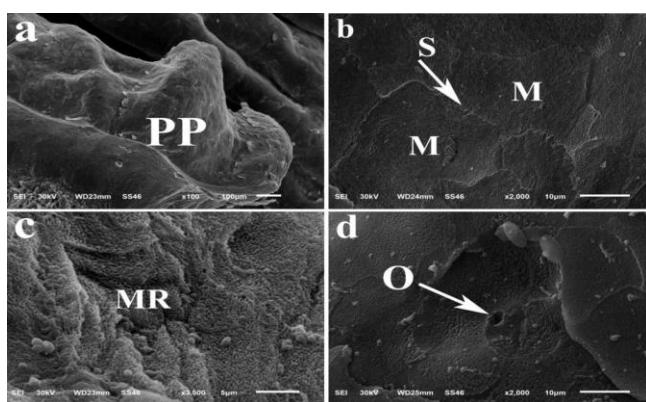


Figure 11: Scanning electron micrographs of camel hard palate a (Incisive papilla) b, c and d showing: (PP) Palatine papillae, (M) Microplacae, (S) Septae, (MR) Microridges and (O) Openings of the duct of palatine salivary gland.

## Discussion

The present study showed that, the hard palate is divided into a narrow elongated rostral part and a caudal wide part, which it commenced suddenly at the level of the third premolar tooth. These results are in contrast with Farrag *et al.* (30) in Egyptian water buffalo, it appeared as bottle-shaped hard palate into wide rostral and caudal parts, and a narrow middle part. This result is in accordance with Mahdy *et al.* (31) in Egyptian goat. In the current work, the hard palate is bounded rostrally and laterally by the upper dental arch and continued laterally with the gums and caudally with the mucous membrane of the soft palate. This result was similar to that described in ruminants by Farrag *et al.* (30). In contrast to Maala *et al.* (32), the hard palate showed various degrees of pigmentation.

The length of hard palate of camel in the present investigation 30.1cm, similar finding was reported by Farrag *et al.* (30). Encarnacion *et al.* (33) added that there is a positive relationship between the length of the hard palate and the time for grinding of coarse feed inside the mouth. The relatively long hard palate of the camel permits efficient grinding of coarse roughages, thorns and cactus before swallowing. The number of palatine ridges in the current work study was 13-14 pairs. Previous studies reported the presence of 12-15 palatine ridges in Egyptian goat (31), 10 pairs in sheep (33). It was 18 on the right side and 19 on the left side (14) in Egyptian water buffalo, 15-19 in bovine (34) 16-20 pairs in yak (35). The differences of the number of palatine ridges are due to the species differences. The presence of larger number of palatine ridges together with caudally directed free borders increase the efficiency of the hard palate in directing the food backwards.

The rostral end of hard palate presents a semilunar in shape dental pad serves as a counterpart to upper incisors as a crescentic thick plate. It is suggested that the well-developed dental pad might assist camel during ingestion of coarse roughages thorns and cactus. The incisive papilla is triangular in shape, in this study, it is similar to in Egyptian water buffalo while it was rounded in Egyptian goat, heart-shaped in Rahmani sheep and it was a diamond shaped in Sambar deer (36). The palatine raphae began as crest, then at the level of the first premolar the crest transformed to groove. Different results were recorded in Egyptian goat, it was in the form of a prominent groove, a shallow groove in Egyptian water buffalo and straight groove in Rahmani sheep (37).

The histological findings of the hard palate were coincided with the other ruminants, which explained the mucous membrane of the hard palate and incisive papilla were lined by highly keratinized stratified squamous epithelium. In accordance Farrag *et al.* (30) in Egyptian water buffalo, the rostral surface was highly keratinized than the caudal one. Encarnacion *et al.* (33) clarified that the highly keratinized epithelium in the hard palate protected the

mucosa from injurious of sharp ingested food. The mucosa of the hard palate is subjected to heavy mechanical loads. The propria-submucosa was dense irregular connective tissue separated by epithelial pegs. The well vascularized collagen fibers were arranged in thick bundles in various directions. This finding was in agreement with Farrag *et al.* (30). The adipose tissue was distributed at palatine ridges (30,37).

In accordance with the current results Farrag *et al.* (30) and Sreeranjini *et al.* (36) recorded that the caudal smooth part of the hard palate had palatine glands. In the contrary of that the palatine glands were located at the rough and smooth parts of the wide part of the hard palate (37). Nabipour (38) also recorded that the palatine salivary glands were placed in the caudal part of the hard palate and in the entire length of the soft palate of camel. The stratified squamous epithelium and, micropliae system may play an important role in the mechanical protection of the surface of hard palate during prehension and mastication (39). The current work revealed that, there are excessive desquamations and sloughing of the epithelial cells, this result was supported by Martinez *et al.* (40) and Mahdy *et al.* (41).

The presence of thick and highly keratinized epithelium in the hard palate provides a protection to the underlying layers of mucosa from damaging by abrasions from ingested food. The masticatory mucosa of the hard palate is subjected to heavy mechanical loads; therefore, the horny epithelium modifies to adapt these mechanical loads. The desquamation and sloughing of the epithelial cells of the palatine rugae, which were shown in the current work, might be due to the mechanical loads on these rugae during the mastication and swallowing of the food. The current work demonstrated, that micropliae system, which it informs of irregular surface separated by septae. Similar results were mentioned in Rahmani sheep (37) and in contrary to Mahdy *et al.* (31), who mentioned that the micropliae had a honeycomb appearance.

At higher magnification, the surface of the palatine ridges, dental pad and incisive papilla revealed folds, micropliae. The mucosa of the hard palate consists of stratified squamous epithelium and are subjected to mechanical stress through rubbing against other surfaces of foreign objects during food prehension and mastication, therefore, micropliae furnish mechanical protection by decreasing the frictions between the contact surfaces and reduction of the surface area.

## Conclusion

The present study explains the primary macro- and micro-morphological characteristics mucosa of hard palate in the camel. The camel's hard palate had particular acclimation which could increase its effectiveness throughout ingestion and mastication of coarse roughages, thorns and cactus. Furthermore, this study will assist in

comparison with that of other ruminant animals; also, it might be as a reference guide for the interpretation of normal and pathological conditions.

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## Conflict of interest

The authors declare that they have no conflicts of interest.

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## الصفات العيانية والنسجية والمجهرية الإلكترونية لبطانة الحنك الصلب في الجمل أحادي السنام

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### الخلاصة

الغرض من هذا العمل هو دراسة بطانة الحنك الصلب للإبل عن طريق التشريح الكلي والتحليل المورفومتري بالإضافة إلى الفحص المجهرى الضوئي والمسح الإلكتروني. تم جمع عشرة من رؤوس الإبل حديثة الذبح من مجزر الزقازيق. كانت الإبل المختارة بحالة عامة جيدة تراوحت أعمارهم بين ثلاث إلى خمس سنوات، من كلا الجنسين. من الناحية التشريحية، كان الحنك الصلب ممدوداً ويمكن تقسيمه إلى جزء أمامي ضيق وجزء خلفي واسع ويحتوي على حوالي 13-14 نتوء حنكي مستعرض. كانت الوسادة السننية عبارة عن صفيحة سميكة هلالية في النهاية الأمامية للحنك الصلب. الحلمة القاطعية هي بروز مثلث يقع خلف الوسادة السننية في المستوى الوسطاني ومحاطة بأخدود ضحل. بالمجهر الضوئي، يتكون الغشاء المخاطي للحنك الصلب من ظهارة حرشفية متقرنة. تتكون الطبقة تحت المخاطية من الأنسجة الضامة الكولاجينية الوعائية في اتجاهات مختلفة. يتميز الجزء الخلفي الأملس من الحنك الصلب بوجود عنبيات مصلبة مفصصة وغني بالخلايا الشحمية. أظهر الفحص المجهرى الإلكتروني التقسيم الطبقي للظهارة، مع التفتت المفرط وتفتت الخلايا الظهارية. من خلال التكبير العالي، تم إظهار نظام الطيات الصغرى بسطح غير منتظم مفصول بواسطة الحاجز.