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Functional-Morphological Study of the Oropharyngeal Cavity and the Tongue of the Common Kestrel, (*Falco Tinnunuculus*)

Part I: The Roof of the Oropharyngeal Cavity

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Abstract: *The aim of the present study was to investigate the light and electron microscopic structure of the roof of the oropharyngeal cavity of the common kestrel. The roof of the oropharyngeal cavity of the common kestrel, Falco tinnunuculus is distinguished into two regions; the palate region and the pharyngeal region. The palate region is relatively twice the length of the upper jaw that incubates longitudinal choana and has one medial and two lateral ridges that bears several longitudinal rows of posteriorly-directed and pointed papillae while posteriorly, the palate flaps to form a pair of distinctive palatine wings. While, the pharyngeal region is short, relatively half the length of the palate region and incubates a narrow infundibular fissure, as well as, numerous of the orifices of the pharyngeal salivary gland and also bears several rows of posteriorly-directed papillae which are arranged transversely on its posterior margin "posterior pharyngeal papillae" forming the pharyngeal wing. The palate region of the roof of the oropharyngeal cavity is covered with highly desquamate keratinized stratified epithelium that carrying microridges on its surface. The keratinized epithelium forming the papillae that are scattered on the surface of the palate region, as well as, on the posterior margin "palatine papillae". The epithelium of the palate region is characterized by the disappearance of the dermal papillae. The pharyngeal region is covered by non- keratinized stratified squamous epithelium while the pharyngeal papillae are covered by keratinized epithelium. The epithelium of the pharyngeal region is characterized by the appearance of short and few dermal papillae. The epithelium of the roof of the oropharyngeal cavity becomes transitional- type at the region of the connection with the upper and lower jaw.*

Keywords: *Oropharyngeal cavity; Common kestrel; Roof; tongue; Palate; Pharyngeal; Epithelium.*

1. INTRODUCTION

Bird as a class of vertebrate posses some unique features which have equipped them with the adaptations for diverse conditions of life. The structural adaptations of the feeding apparatus of birds project an interesting subject for functional morphological studies. Knowledge of functional morphology is essential for all types of morphological studies including systematic investigations, Bock (1974). The functional morphological study of the feeding apparatus of any bird essentially includes studies of the various components of the jaw apparatus, lingual apparatus, and laryngeal apparatus. Obviously, movements of all these three complexes are coordinated differently in the complicated feeding and drinking processes in diverse groups of birds. The jaw apparatus of bird is a highly diverse organ showing considerable variability in its size, shape and much of which can be closely related to the feeding mechanism. Despite the large amount of the anatomical information concerning the avian jaw apparatus, little was know about the morphological and functional differences and peculiarities among this system e.g. (Bühler, 1981; and Bock (1964)). The epithelium lining the jaw apparatus especially the roof of mouth was given little attention such as; Zusi (1962) has made extensive studies on the black skimmer operations of these bird; Goodman and Fisher (1962) who have given an excellent account of the functional anatomy of the feeding apparatus in waterfowls; Raval (1973) who was studied the epidermal structures of four Falconiform predatory birds in detail and has come across many interesting adaptations; Dubale and Thomas (1978) described the epidermal structures of the tongue and buccal cavity of the Brahminy Myna (*Sturnus pagodarum* Gmelin) and the Wagtail *(Motacillo flava Thunbergi* Billberg). Recentely; the study of the functional morphology of the oropharyngeal cavity has been receiving more attention of the avian anatomists all over the world in recent days, e.g. Homberger (2001) studied the case of cockatoo bill, horse hoof, Rhinoceros horn, whale baleen and turkey beard; the integument as a model system to explore the concepts of homology and non- homology; Crole and Soley (2010) are studied the gross morphology of the intra-oral rhamphotheca, oropharynx and proximal oesophagus of the Emu (*Dromaius novaehollandiae*); Erdogan and Alan (2012) were mentioned the gross anatomical and scanning microscopic studied of the oropharyngeal cavity in the European magpie (*Pica pica*) and the common raven (*Corvus corax*); and Igwebuike and Anagor (2013) were studied the morphology of the oropharynx and tongue of the Muscovy duck (*Cairina moschata*).

However, we were noticed that the common kestrel, Falco tinnunculus were not given such attention which is avian predators, have a voluminous tongue. Thus, the question is "What are the structure of the buccal cavity of the kestrel?" and "Is there modification in their components establishing the roof of the oropharyngeal cavity of the kestrel to facing the feeding behavior? These questions are attracted the attention to be the aim of the present work. The present study of functional morphology of the roof of the oropharyngeal cavity of the common kestrel attempts to correlate the structure of the different components with contemplate mechanical performance during the feeding process. The present study was carried out depending on several biological techniques; general histological, histochemical and scanning electron microscopical technique, in addition to the essential tool in any anatomical investigations which is stereomicroscope.

2. Material and Method

The specimens of the common kestrel brought alive to the laboratory, and then were killed by ether or chloroform inhalation. The specimens were dissected under a wild M3-stereomicroscope with camera Lucida attachment. For the observations in light microscope; the epithelium of the roof was separated from the rest of the skull and then was fixed in neutral formalin solution for about 3-10 days, and washed in 70% ethyl alcohol for about 48-hrs. The tissue was immersed in a neutral EDTA solution for about 10-15 days to decalcify the bony elements. Next tissue were dehydrated through ascending series of ethyl alcohol, then cleared through three changes in methyl benzoate and embedded in paraffin wax. The 7- 8µm thick histological slides were stains by Haematoxylin-Eosin stains technique (H&E). "Drury and Wallington (1980)", Masson's trichrome stain "Masson (1929), and Orcein stain " Unna (1891).

For the observations in scanning electron microscope (SEM) the tissue were cut to small pieces fixed in 5% glutraldehyde in a cacodylate buffer for at least 48 hrs at pH=7.2 and at 4°C then washed three times in 0.1% cacodylate buffer. Next tissue were post fixed in a cacodylate-buffered-solution of 0.1% Osmium tetroxide for 2-hrs at 37°C. Then tissue were dehydrated through ascending series of ethyl alcohol and infiltrated with amyl acetate two days, and then dried by the critical point during using liquid carbon dioxide. The tissue was mounted and sputter-coated with gold and examined under A Jeol Scanning Electron Microscope (JSM-5400 LV), at 15 Kv.

3. Results

3.1. Macroscopic Observations

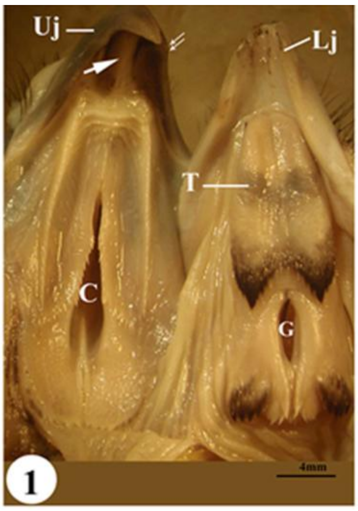

Fig1. *Photomicrograph of the buccal cavity of Falco tinnunculus, showing Consistency between the shapes of the roof of the mouth to the form of the tongue*

The roof of the oropharyngeal cavity of the common kestrel, Falco tinnunuculus is distinguished into two regions; 1- the palate region and 2- the pharyngeal region.

The palate region is relatively twice the length of the upper jaw that incubates a longitudinal fissure "choana, C" through which the oral and nasal cavities communicate. The choana initiates narrow anteriorly then become wider posteriorly, (Figs.1& 2).

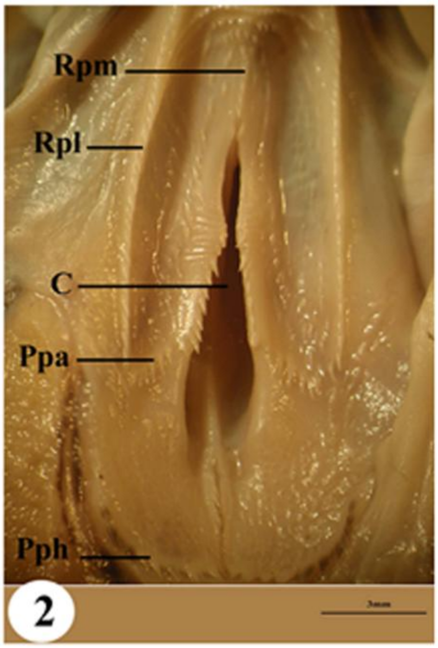

Fig2. *the roof of the mouth of Falco tinnunculus, showing the lateral palatine ridge (Rpl) and medial palatine ridge (Rpm), this region incubates the longitudinal fissure (Choana, C) and bears transverse row of posteriorly-directed papillae, the palatine papillae (Ppa). Beside a row of posteriorly-directed papillae is arranged transversely on the posterior margin of the pharyngeal region (posterior pharyngeal papillae, Pph)*

The exoskeletal derivatives of the palate roof form one medial and two lateral ridges. The lateral palatine ridge (Rpl) lies on each side of the choana, and is supported by the palatine bone. Each of the lateral ridges bears number of posteriorly-directed papillae arranged regularly in longitudinal rows, (Fig. 3). The medial palatine ridge (Rpm) is located anterior to the choana and bears also a several longitudinal rows of posteriorly-directed and pointed papillae which are extended to arrange on the margin of the choana, (Fig. 4).Anterior to the medial ridge of the palate region, the mucosa of the palate epithelium gives rise to the medial inverted bulge and lateral series of arch-like ridges, (Fig. 3).

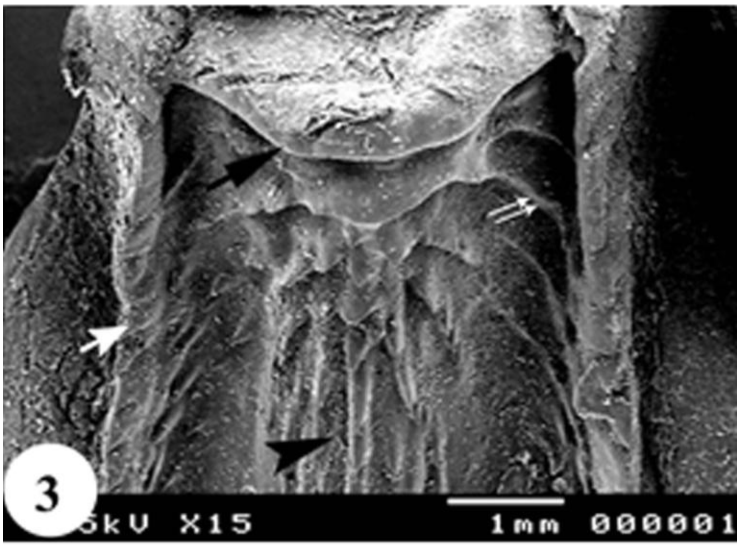

Fig3. *Scanning electromicrograph of the most anterior part of the palate region of Falco tinnunculus, showing the mucosa of the palatal epithelium which gives rise to the antero-medial inverted mound (black arrow) , lateral series of arch-like ridges (double arrows). In addition, the lateral ridge bears rows of the posteriorly-*

directed papillae "lateral palatine papillae (white arrow) and medial ridge bears longitudinal rows of posteriorly-directed and pointed papillae "medial palatine papillae" (head arrow)

Moreover, the region of the palate that lies between the right and left lateral ridges is the medial palatine groove, its bears scattered posteriorly-directed papillae, (Fig. 3). While, the region lies between the lateral ridge and the edge of the upper jaw being the lateral palatine groove. The medial groove fails to extend posteriorly to the level of the choana. Obviously, the lateral groove incubates the lower mandible when the bill is closed.

Posteriorly, the palate flaps to form a pair of distinctive palatine wings, each of which bears one transverse row of posteriorly-directed papillae "palatine papillae, Ppl", (Figs.4& 5).

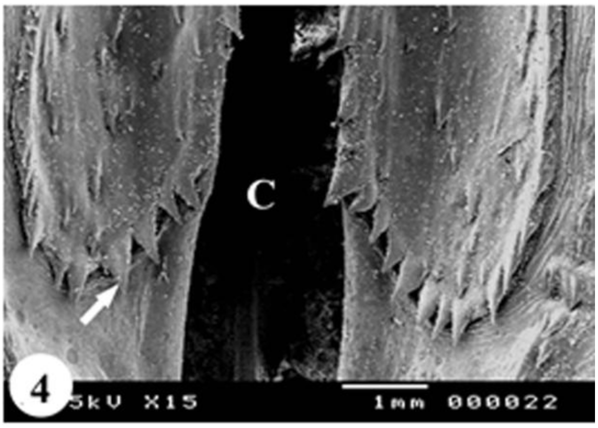

Fig4. *Scanning electromicrograph of the posterior part of the palate region of Falco tinnunculus, showing the choana (C) and the palate wings that bear one transverse row of posteriorly- directed papillae (arrow). (15x)*

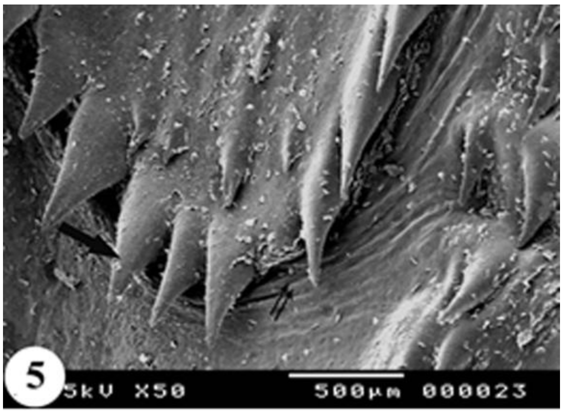

Fig5. *Scanning electromicrograph of the palate wing of Falco tinnunculus, showing the posteriorly-directed papillae (palatine papillae) (arrow) and its surface with detached keratin (double arrows). (50x)*

The pharyngeal region of the common kestrel is short, relatively half the length of the palate region and incubates a narrow infundibular fissure. The fissure bears on their medial margins number of pointed and overlapped papillae which are arranged in one longitudinal row of postero-medial direction, (Fig. 6).

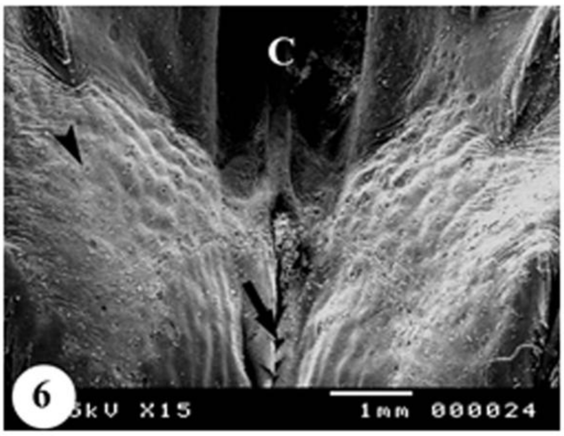

Fig.6. *Scanning electromicrograph of the pharyngeal region of Falco tinnunculus, showing many pores of the posterior pharyngeal salivary gland (head arrow) and overlapped medial pharyngeal papillae which are arranged on infundibular margins (arrow). In addition, the choana (C) appeared distinct. (15x)*

The surface of the pharyngeal region is provided with a numerous of the orifices of the pharyngeal salivary gland and also bears several rows of posteriorly-directed papillae which are restricted on its posterior surface and are arranged transversely on its posterior margin (posterior pharyngeal papillae, Pph) forming the pharyngeal wing, (Figs.7).

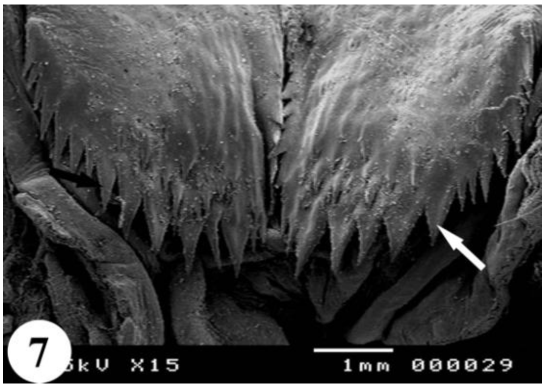

Fig7. *Scanning electromicrograph of the pharyngeal region of Falco tinnunculus, showing several rows of posteriorly-directed papillae which arranged transversely on its posterior margin (posterior pharyngeal papillae) (arrow). (15x)*

3.2. Microscopic Observations

The roof of the oropharyngeal cavity of the common kestrel is covered by a stratified squamous epithelium with distinct keratinized layer like that of the most typical birds.

The most anterior portion of the palate region of the common kestrel is voluminous and bulgy. The anterior inverted bulge "antero-medial inverted mound" is distinguished with series of arch-like ridges, (Fig. 3). The histological investigation revealed that mound arises from the thickness of the mucosa layer. Moreover, the mucosa is covered by thick keratin layer, (Fig. 8). SEM investigation shows the presence of the deciduous epithelium, (Fig. 9).

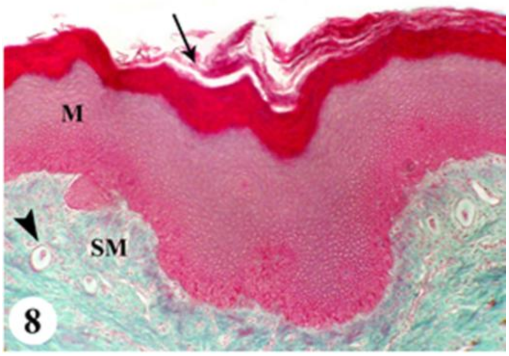

Fig8. *Photomicrograph of a transverse section through the most anterior part of the palate region of Falco tinnunculus, showing the antero-medial inverted mound which arises from the thickness of the mucosa layer (M) which is covered by thick keratin layer (arrow). In addition, the submucosa layer (SM) is filled with collagenous connective tissue and numerous of sensory organs "Pacinian corpuscles" (head arrow). (Trichromic, 400x)*

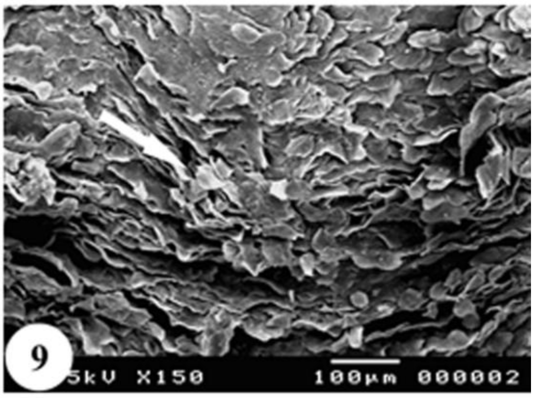

Fig9. *Scanning electromicrograph of the most anterior part of the palate region of Falco tinnunculus, showing the presence of the deciduous epithelium (arrow)*

The palate region possesses two lateral ridges and one medial one, which bear the posteriorly-directed papillae. The most posterior portion of the palate region carries one row of the papillae which known as "palatine papillae, Ppl". SEM investigation revealed that the palatine papilla is smooth with deciduous keratin, (Fig.5). The histological investigation shows that the submucosa of the palate epithelium of the common kestrel gives rise to the core of the papillae while the mucosa is keratinized epithelium and forms the outer envelope of the papillae. In addition, these papillae lack dermal papillae, (Fig. 10).

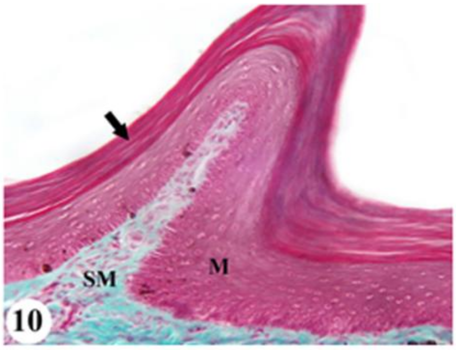

Fig10. *Photomicrograph of a transverse section of the palate region of Falco tinnunculus, showing the mucosa of the palate epithelium (M) which is composed of stratified squamous epithelium and covered by thick keratin layer (arrow) and submucosa (SM). In addition, the mucosa lacks the muco-submucosal junctions. (Trichromic, 400x)*

SEM investigation along the whole length of the palate region of the common kestrel revealed the presence of deciduous epithelium with borders of the epithelial cells. Moreover, many tiny papillae are scattered along the whole surface of the palate region. High magnification of SEM reveals the surface of the palate region is characterized by the presence of microridges (Figs. 4& 11).

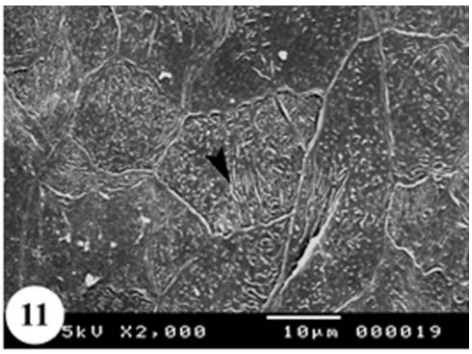

Fig11. *Scanning electromicrograph of the palate region of Falco tinnunculus, showing the presence of the microridges on its surface (head arrow). (2.000x)*

Histological investigation along the whole length of the palate region shows that the mucosa of the palate epithelium of the common kestrel is covered by thick keratin layer (Figs. 12& 13). Also the mucosa lacks the dermal papillae.

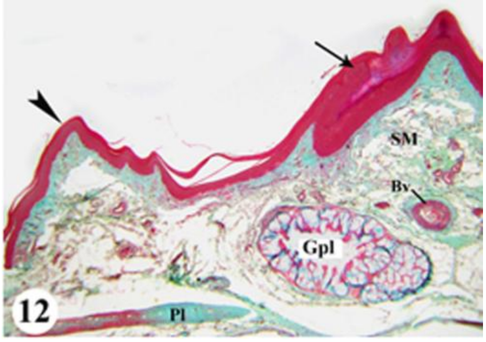

Fig12. *Photomicrograph of a transverse section through the palate region of Falco tinnunculus, showing lateral ridge (head arrow) and medial ridge bears papillae (arrow). Beside the anterior palatine salivary gland (Gpl), the palatine bone (Pl) and the submucosa (SM) which contains blood vessels (Bv) are well represented. (Trichromic, 40x)*

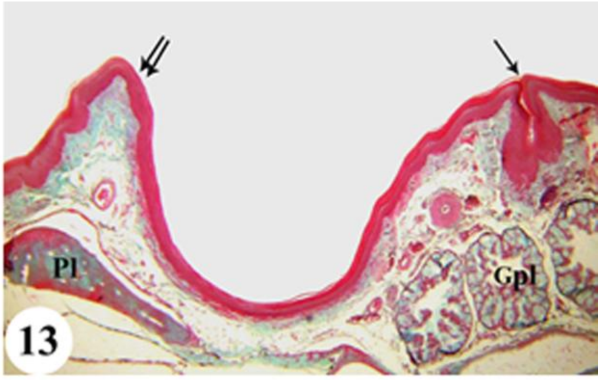

Fig.13. *Photomicrograph of a transverse section through the palate region of Falco tinnunculus (at the beginning of choana), showing the choana and their margins (arrow) and lateral ridge of the palate region (double arrows). Beside the location of the anterior palatine salivary gland (Gpl) and the palatine bone (Pl). (Trichromic, 40x)*

The epithelium covering the pharyngeal region of the common kestrel is non-keratinized stratified squamous epithelium, (Fig. 14). However, the keratinization appears only on the papillae which are arranged lateral to the infundibular fissure and most posterior portion of the pharyngeal region (Fig. 15). These papillae have the same structure of the palatine papillae.

Fig14. *Photomicrograph of a transverse section through the pharyngeal region of Falco tinnunculus, showing the pharyngeal region is covered by keratinized epithelium (head arrow) and the infundibular fissure (arrow). In addition, the posterior pharyngeal salivary gland (Gph) and its relation to fasica of the pterygoid muscle (Pt) (double arrows). (Trichromic, 400x)*

Fig15. *Photomicrograph of a transverse section through posterior part of the pharyngeal region of Falco tinnunculus, showing the pharyngeal wing which bears the pharyngeal papillae (arrow) and incubates the posterior pharyngeal salivary gland (Gph). In addition, the infundibular fissure (head arrow) and the pterygoid muscle (Pt) are well represented. (Trichromic, 40x)*

Histological investigation of the pharyngeal region revealed that the mucosa of the pharyngeal epithelium is characterized by the presence of dermal papillae, (Figs. 14& 16). SEM investigation shows that the surface of the pharyngeal region is smooth with detached epithelium, as, well as the appearance of numerous orifices of the pharyngeal salivary gland (Gph), (Fig. 17).

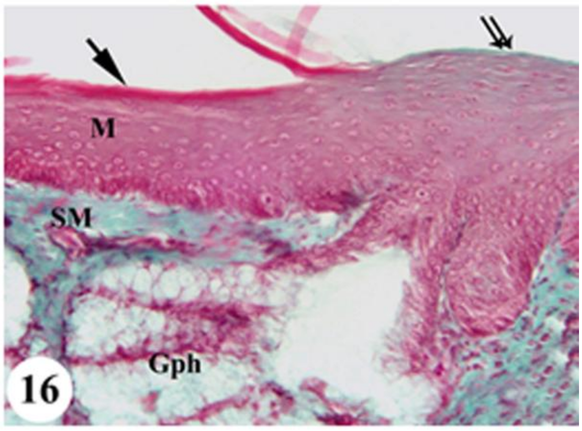

Fig16. *Photomicrograph of a transverse section through the pharyngeal region of Falco tinnunculus, showing mucosa of the pharyngeal region (M) is composed of the keratinized stratified squamous epithelium (arrow) which becomes non-keratinized (double arrows) at the opening of the posterior pharyngeal salivary gland (Gph). In addition, the submucosa (SM) is distinct. (Trichromic, 400x)*

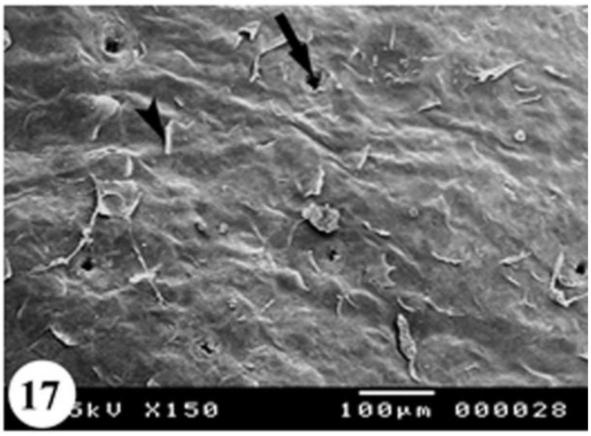

Fig17. *Scanning electromicrograph of the pharyngeal region of Falco tinnunculus, showing many pores of the posterior pharyngeal salivary gland (arrow). The surface of the pharyngeal region is smooth with detached keratin (head arrow). (150x)*

The epithelium of the roof of the oropharyngeal cavity of common kestrel becomes transitional-like epithelium at the lateral groove (the site of the connection of the roof of mouth with the upper jaw),

(Fig. 18). SEM investigation shows the presence of mucosal ridges which are characterized by smooth surface with some deciduous epithelium, (Fig.19). By using a high magnification of SEM, the borders of the deciduous cell are well observed, (Fig.20).

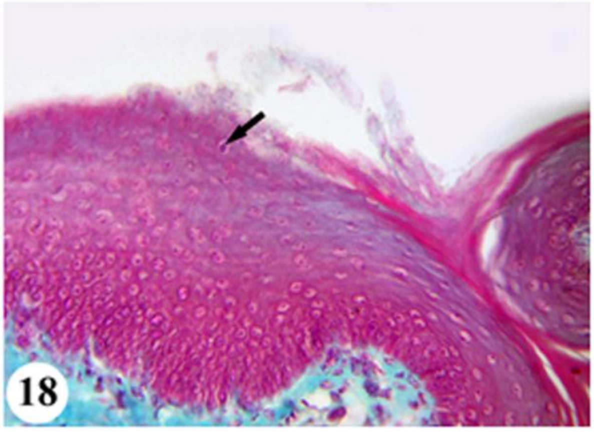

Fig18. *Photomicrograph of a transverse section through posterior portion of the pharyngeal region of Falco tinnunculus, at the connection of the roof of mouth with the upper jaw, showing the keratinized epithelium becomes transitional-like epithelium (arrow) in this region. (Trichromic, 400x)*

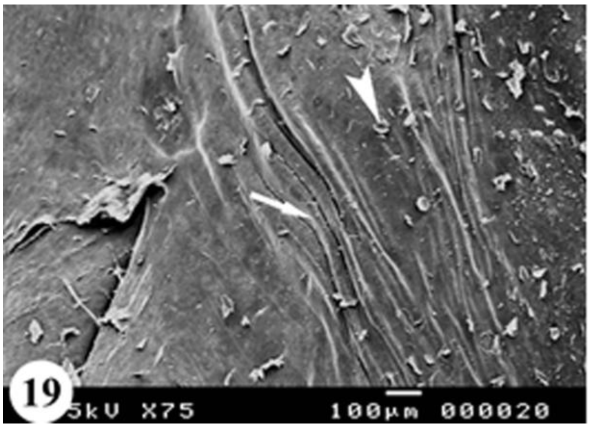

Fig19. Scanning electromicrograph of the surface of the roof of the mouth of Falco tinnunculus, showing the presence of mucosal ridges (arrow). (75x)

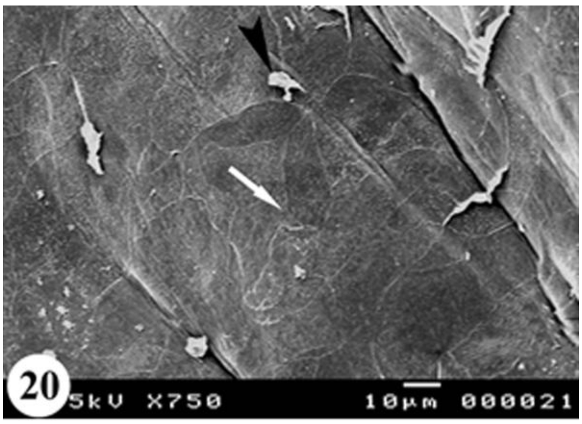

Fig.20. *High magnification of Fig.(19), showing the smooth surface of the mucosal ridges and the appearance of the intercellular borders of the outer cellular layer (arrow). (750x)*

4. DISCUSSION

With gradual increasing complexity in higher vertebrate structure and function, the birds as a class of vertebrate have acquired a high degree of feeding adaptations for diverse food-niches (Bhattacharyya, 1994). The common kestrel, *Falco tinnunculus* is a prey-predator bird live in dry environment. The kestrel depends on its claws in catching and on its sharp curved beak in kill and cutting the prey, following by picking up and manipulating the flesh piece by piece to the buccal cavity by the tongue. Then the tongue transfers the food items toward the esophagus. Mahmoud (2009) was suggested that the kestrel is considered as lingual feeder like the kite described by Shawki (1995)

However, the roof of the oropharyngeal cavity as a subdivision of the oropharyngeal cavity and the beak are lining by the epithelium which exhibits a great regional variations. The epithelium reflects a great adaptation facing the different forces. Those forces are external from the abrasion forces of the food items and the lingual apparatus, and internal from the mechanical performance of the jaw apparatus itself. Going through the literature, it has been found no one interest about the epithelium that lining the roof of the oropharyngeal cavity compared to that of lingual apparatus.

The epithelium lining the roof of the oropharyngeal cavity of the common kestrel exhibits extreme regional variations. Since, the highly strong keratinized epithelium spreads on the surface of the palate region of the roof of the oropharyngeal cavity of the kestrel may counteract the abrasive force. The thickness of epithelium of the palate region of the kestrel forming the antero- medial inverted mound That is due to the demand of proliferation of the germinal cellular layer compensating the loss of the superficial cellular layer. That may elucidate the thickest epithelium which is found in the regions that more exposed to abrasion forces from the food items or/and from the movement of the tongue.

The highly keratinized epithelium is the most prominent among the roof of the oropharyngeal cavity of the common kestrel; the palatine and pharyngeal papillae, as well as, the papillae are arranged in several longitudinal rows on the lateral and medial ridge of the palate region. These papillae are keratinized pointed and posteriorly- directed. They can adjust their position to perform holding and pushing the food items during the protraction and retraction of the tongue. Thus it has been expected that these papillae of the roof of mouth of the kestrel may have a role in processing the food items. Dubal and Thomas (1978) observed that the epithermal structure of the buccal cavity and tongue of Brahminy Myna (*Sturnus pagodarum*) and the Wagtail (*Motacilla flava*) and pointed out about this point that the palatal folds and the spiny outgrowths of the epidermis help in holding the food, as well as, transporting it towards the gullet.

Non-keratinized stratified epithelium lining the pharyngeal region of the roof of the oropharyngeal cavity because this region is less exposed to abrasive forces. Since, this region is a pathway for the food to the esophagus. Therefore, the presence of the salivary gland opening to secrete saliva for facilitates the swalling process.

Moreover, non- keratinized epithelium of transitional type lining the connection of the roof of the oropharyngeal cavity with the rhinothecal of beaks, which means that it is the place from which arise the main movements of the beaks. Mahmoud (2009) described that the epithelium of transional- type lining the connection of the tongue with the floor of the mouth and suggested that from it arise the main movements of the tongue. The transitional epithelium has a stretching ability and consequently its existence is a demand adaptive for the mechanical performance of the jaw apparatus.

The non- keratinized and keratinized epithelium of the roof of the oropharyngeal cavity carrying microridges that may help in spreading the mucous on the surface of the roof of the oropharyngeal cavity and may be associated with the demand of the dry condition to providing the friction.

The mucosa-submucosal junctions exhibit variable extension in this existence, distribution and elongation among the type of epithelia of the common kestrel. These junctions disappear along the well-keratinized palate region, the palatine and pharyngeal papillae.

While they exist as short junctions among the pharyngeal region of the kestrel, as well as, they contain elastic fibers. These junctions are associated with the demand of the shape configuration of the surface.

5. Conclusion

The present work showed that there is orthokeratinized epithelium. This type of epithelium is a hard epithelium which spreads along the roof of the oropharyngeal cavity of the kestrel and can't change its shape according to its use; consequently its existence is associated with the restriction of the movement of the upper beak of the kestrel.

Therefore, the epithelium of the roof of the oropharyngeal cavity of common kestrel exhibits a great adaptation with the mechanical performance of the jaw apparatus, as well as, the food items and movement of the lingual apparatus.

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