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A review on comparative morphology of avian oral cavity

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Abstract
The anatomy of the avian oropharyngeal cavity is crucial in considering the structural variances. In Turkey and Japanese quail, the mouth and pharyngeal cavity was not well demarcated. In duck and goose the fusion of bony plate of upper beak with the nasal and premaxillary bone is movable. Palatine bones are in the form of bony plates noticed in goose and duck whereas rod- shaped in fowl and pigeon and are extend parallel to one another and articulate with the maxilla anteriorly and pterygoid posteriorly. Vomer bone is a thin, unpaired bony plate in duck and goose whereas it is rudimentary in fowl and pigeon. Quardate bone is noticed in between the neurocranium and the maxillopalatine apparatus. Mandibular joint is formed by the articular surface of the mandibular bone also has a large foramen pneumaticum in the duck and goose. In duck and geese, supra-angular bone is in the form of a prominent muscular ridge. In duck and goose branches of the mandibular nerve exit by many numerous prominent openings and are situated on the mandibular rami both on the internal and external surfaces arranged in rows mainly in the oral region. The horizontal movement of the upper beak quadrate bones is by the medially placed pterygoid, palatine bones and zygomatic bones and the movement is at its base in the craniofacial hinge helps in the movement of the upper beak at its vertical direction along with the movement of the lower beak, this movement helps in food uptake. Hyoid bone is slender in the fowl and pigeon whereas it is flattened in the duck and goose.

Keywords: Duck, domestic fowl, beak, tongue and hard palate

Introduction

Understanding the anatomy of the oropharynx is necessary to comprehend the morphological changes in a bird oral cavity. The anatomy of the avian oropharyngeal cavity is crucial in considering the structural variances that may affect nutrition, food intake and swallowing since birds have unique feeding patterns and corresponding differences in their oropharyngeal cavity. In bird teeth were absent. In addition to having no teeth, limited functioning cheek, lip muscles developing into upper and lower beaks, bird jaws differ from those of mammals in how they manipulate food (Nickel *et al.*, 1977; King and McLelland, 1984; Reece, 1996) [31, 23, 35]. The formation of the jaws of birds into upper and lower beaks and the absence of teeth and lips and cheeks with limited functional muscles, the manipulation of feed is different from mammals (Nickel *et al.*, 1977; King and McLelland, 1984; Reece, 1996) [31, 23, 35]. The oropharyngeal cavity has lingual apparatus which helps in the regulation of various functions and consists of many elements, the salivary glands, muscles, bony skeleton and cartilage influencing one another mechanically (Homberger and Meyers, 1989) [13]. According to several studies (Nickel *et al.*, 1977; Emura *et al.*, 2008; Parchami *et al.*, 2010) [31, 6, 33], the morphological adaptations of avian tongues are strongly related to the diversity of feeding adaptations among birds. This is supported by the shape and function of the feeding apparatus in birds. Birds have different glandular structures on their tongue, palate, and pharynx in the upper digestive tract. The tongue, palate and pharynx of birds had a characteristic feature of glandular structures in the upper digestive tract. Menghi *et al.*, 1993 [28]; Samar *et al.*, 1995 [37-38], Kobayashi *et al.*, 1998 [24]; Liman *et al.*, 2001 [25]; Jackowiak and Godynicki, 2005 [19]; Crole and Soley, 2009 [3], no uniformity had been achieved with regard to the localization and naming of these glandular structures (Crole and Soley, 2009) [3]. Salivary glands, muscles, bones and cartilage are just a few of the parts that make up the oropharyngeal cavity of the lingual apparatus, which helps to manage a number of functions

(Homberger and Meyers, 1989) [13]. The floor of the oropharyngeal cavity in many avian species had a furrow-like depression lodging the tongue between the rami of the mandibule of lower beak.

Boundaries of oral cavity

Birds head were made up of a large cranium and differ from mammals in moving their upper mandible rather than the lower, relative to the cranium. The nature of food size and type of food prehension also decides the shape of the beak and size of beak (McLelland, 1979) [27]. The regulation of ingestion is an important factor in determining the size of the beak and are sharp with a flexible thick horny sheath. The horny sheath of beak is tough and firm in fowl and pigeon but doughy and pliable in the duck and geese. Upper beak consists of the base, the curved dertrum, the dorsum, the lateral surfaces with sharp borders otherwise called as upper tomium (McLelland, 1979) [27]. The lower beak consists of the slant, the rami and the borders otherwise known as lower tomium. The borders of the lower and upper beak sheaths are pointed. The spoon shaped bill is protected with pliable, light golden coloured smoothy ceroma in duck and goose (McLelland, 1990) [26]. The sharp point of the beak with rigid horny plate, like a claw with the wide variety of texture in the beak was noticed in different species of birds King and (McLelland, 1984) [23]. The smooth glistening skin is seen at base of the beak in fowl and slight enlargement in pigeon the cere. The borders of the upper and lower beak in duck and geese are composed of horny lamellae in perpendicular arrangement. The horny lamellae act as a filter in ducks and geese while taking feed from water. The upper and lower beak protects the oropharyngeal cavity in fowl. The bony plate of the upper beak was formed by incisive bone and lower beak was formed by the anterior part of the mandible, described in birds (Nickel *et al.*, 1977) [31], fowl (Sisson and Grossman, 1975) [39] and ostrich (Tadjalli *et al.*, 2008) [41].

Incisive bone

The incisive bone and mandible were over lined by thick horny tissue, the beak. The lower beak was overlaid by the upper beak. The greatest part of the upper beak was formed by the incisivum bone and variation in shape and size of the beak in the different species of birds was also due to the paired incisive bone (King and McLelland., 1984) [23] upper beak of the bird is composed of a bone called the maxilla; the lower beak is composed of a bone called the mandible. The paired incisivum bone (premaxillary bone, intermaxillary bone). The incisive bones of the mandible is overlined by dense, horny skin overlying the beak and no birds possess teeth but rudimentary enamel organs have been recorded in the embryos of some birds known as the egg tooth, is a short elevated, cone shaped keratinised epidermal cells of the upper beak at its dorsum of the chick, helps in hatching out by piping the shell and goes off at the first days of life (McLelland, 1979) [27]. In all the birds, the lower beak was covered by upper beak when the mouth was closed. The shape of the beak varied in different birds. Broad base and pointed tip with slightly curved beak in turkey and strongly curved in chicken and Japanese quail (Rajathi *et al.*, 2020) [34]. The incisive bone and mandible were over lined by thick horny tissue, the beak. The lower beak was overlaid by the upper beak. In duck and goose the fusion of bony plate of upper beak with the nasal and premaxillary bone is movable (Nickel *et al.*, 1977) [31]. Duck had wide and trowel shaped bill whereas pigeon had sharp beak (Nickel *et al.*, 1977) [31].

Table 1: Show birds based on feeding habits, examples

Birds based on feeding habits	Examples
Carnivore Birds	Hawks, falcons, eagles, vultures and owls
Granivorous	Finches, Sparrows
Omnivores	Chickens, Crows, Rhea
Frugivore	Parrot, Budgerier
Herbivores	Swan, Geese, Duck, Pigeon, Dove
Piscivores	Pelican, Fishing Eagle
Molluscivore	Owl, Ostrich, Red Tail Hawk
Nectivore	Sun Bird, Humming Bird

Birds Beaks & Adaptations (sciencemadefun.net)

Maxillary Bone

Maxillary bone is small and they form the caudal rim of the upper beak and part of the bony plate and fused with the nasal and premaxillary bones in fowl and pigeon with the palatine and zygomatic bones. The maxillary processes and frontal processes are fused with the frontal and maxillary processes of the premaxillary bone and these form the rostral and lower limit of the nares (McLelland., 1979) [27].

Zygomatic Bone

Thin rod-like prolongation, the zygomatic bone forms the rim of the upper beak, form movable joints with quadrate bones, placed towards caudal direction. Jugal process of the maxillary bone, the jugal and quadratojugal are the three fused bones (Nickel *et al.*, 1977) [31].

Palatine

Palatine bones are in the form of bony plates noticed in goose and duck whereas rod- shaped in fowl and pigeon and are extend parallel to one another and articulate with the maxilla anteriorly and pterygoid posteriorly (McLelland., 1990) [26]. The small and thick flattened bones, pterygoid bone articulate with the palatine bone, sphenoid bones and quadrate bone on the either side (Nickel *et al.*, 1977) [31].

Vomer

Vomer bone is a thin, unpaired bony plate in duck and goose whereas it is rudimentary in fowl and pigeon (Nickel *et al.*, 1977) [31]. Vomer bone in the median plane divided posterior nares to two slits and communicates with the nasal septum and articulates cranially with maxillary bones and posteriorly with sphenoid bone at the rostrum in duck and goose (king and McLelland., 1984) [23].

Quardate Bone

Quardate bone is noticed in between the neurocranium and the maxillopalatine apparatus. (King and McLelland, 1984) [23] Oticus processes, articulatio quadratomandibularis and Orbitalis process are the three articular processes, of which oticus processes with the articular groove of the squamous temporal bone forms a movable joint (McLelland, 1990) [26]. Articulatio quadratomandibularis, articular process articulates with the mandibule by a condyle and also with the pterygoid bones forms a joint. Orbitalis process, towards the orbit, acts as a muscle lever (Nickel *et al.*, 1977) [31].

Maxillopalatine Apparatus

Maxillopalatine apparatus allows the bird to move its upper jaw vertically. This vertical movement of upper jaw is due to the association of quadrate bone with the squamous temporal bone articulate to form quadrato squamosa, quadrate bone articulates with the zygomatic bone to form quardatozygomatica and quadrate bone articulate with pterygoid bone to form quadrato pterygoidea (McLelland., 1990) [26]. The specialized structures were also noticed, pterygoid and sphenoid bones articulate to form the pterygoid eosphenoidea, the palatine and pterygoid bones articulate to form the palate pterygoidea and the palatine and maxillary bones articulate to form the palatomaxillare (King and McLelland., 1984) [23]. The horizontal movement of the upper beak quadrate bones is by the medially placed pterygoid, palatine bones and zygomatic bones and the movement is at its base in the craniofacial hinge helps in the movement of the upper beak at its vertical direction along with the movement of the lower beak, this movement helps in food uptake (Dyce *et al.,* 2002) [5]. Mandibular ramphotheca was bounded ventrally by the rostral part of the oropharynx and dorsally by the maxillary ramphotheca (Tivane *et al.,* 2011) [42] in Ostrich.

Hyoid Bone

Hyoid bone extends both cranially and caudally by two rami of the hyoid and has an unpaired body. Hyoid bone is slender in the fowl and pigeon whereas it is flattened in the duck and goose (McLelland, 1990) [26].

Body of the hyoid on either side carries an articular surface for the rami of the hyoid. Body of the hyoid at its anterior end has an articular surface for the double entoglossal bone in the fowl whereas in duck and geese it is trowel-like (King and McLelland., 1984) [23]. Hyoid body posteriorly connected to the thyroid cartilage by a process known as keel. Lateral to the neurocranium rami of the hyoid bone is noticed and composed of slender bony plates to form a movable joint with the small cartilage at the end of the bony segment at one end and hyoid body at the other end.

Roof of Oropharyngeal Cavity

Hard Palate

The bony hard palate was formed by the palatine process that are combined posteriorly with palatine bones. The hard palate is very narrow in the fowl and pigeon but short in duck and goose with a broad cleft (Nickel *et al.,* 1977) [31]. In Muscovy duck (Igwebuike and Anagor, 2013) [16] and in Ostrich (Tivane *et al.,* 2011) [42] same observations were found, whereas the lateral borders of hard palate in ducks, had lamellae.

Table 1: Roof of Oropharyngeal Cavity

Dromaeognathous Palate	Schizognathous Palate	Desmognathous Palate	Aegithognathous Palate
ostrich, rhea, kiwi	pigeons, fowls, gulls, plovers, cranes, woodpeckers, trogons, etc.	wading and swimming birds, parrots, birds of prey, cuckoos	similar to the Schizognathous crows, swifts, bulbuls
Vomer is large and broad	Vomer is small or absent	Vomer is often abortive or so small	Vomer is short and broad and truncated
Palatines do not articulate with the parasphenoidal rostrum	Palatines and pterygoids articulate with the parasphenoidal	Palatines and pterygoids articulate with the rostrum	Palatines and pterygoids articulate with the parasphenoidal
Maxillo-palatine processes are small do not unite with one another or with the vomer	Maxillo-palatine processes do not unite with one another or with the vomer.	Maxillo-palatines are large and united with one another across the middle line, often forming a flat, spongy palate ventral to the vomer	Maxillo-palatine processes do not unite with one another or with the vomer.
Basipterygoid processes, well developed and Pterygoids fixed	Basipterygoid processes may be absent or small Pterygoids are movably articulated	Basipterygoid processes are absent	Basipterygoid processes may be absent or small Pterygoids are movably articulated

Palatine Ridge

The avian hard palate was characterized by a two lateral palatine ridges and median palatine ridge (Sisson and Grossman 1955) [39]. The anterior two-third part of the hard palate is composed of a median longitudinal fold of mucous membrane, the median palatine ridge was observed. A median ridge (1.42±0.03cm long), two lateral palatine ridges (2.36±0.05 cm long). The median palatine ridge divided the anterior part into right and left sides. The medial palatine ridge extends and ends on both side of the infundibular cleft at the two lateral longitudinal palatine ridges. The posterior part of median palatine ridge was 1.3 cm in turkey and 1.2 in chicken, respectively. The lateral palatine ridge posterior tip extends to the last row of transverse papilla. In between the beak border and the median and lateral palatine ridge the lateral palatine groove was noticed (McLelland, 1990) [26]. In between the beak border and the median and lateral palatine ridge the lateral palatine groove was noticed (McLelland, 1990) [26]. The depth of the lateral palatine groove was more in the hard palate of chicken and Japanese quail whereas the depth of the lateral palatine groove in the anterior part was more and less in the posterior part in turkey and the diameter of the groove was wide in the anterior part and in the posterior part it was less wide. In chicken and Japanesequail the diameter of the groove was same. In chicken and pigeon both median and lateral grooves was present on both side of lateral palatine ridge (Mohamed and Zayed, 2003) [30]. In between the lateral ridges on both side median palatine groove was observed, which was highly concave in chicken and slightly concave in turkey

The hard palate is composed of a median swelling, two lateral palatine ridges and caudally directed papillae arranged in several transverse rows was noticed in fowls and pigeons, whereas the hard palate of the goose has a median and paramedian longitudinal rows of blunt papillae in two to three rows but, in duck along with median longitudinal swelling, caudally directed papillae are restricted to the apical region (McLelland, 1979) [27]. The borders of the hard palate have pointed papillae in both duck and goose (Nickel *et al.,* 1977) [31].

Infudibular Cleft

The anterior apical portion of hard palate is composed of the palatine cleft and based on the size and shape of the beak in the different species it varies and the posterior part of the hard palate is divided by the palatine cleft into two regions (McLelland, 1990) [26]. Palatine cleft at its apical part separated from the edge of the upper beak by the lateral palatine ridges, posteriorly they reach the broad part of the choanal cleft. (McLelland, 1990) [26]. Part of palate framed by the lateral palatine ridges is known as the choanal field. The median palatine groove continues to the level of the infundibular cleft in Japanese quail and the groove holds the seed during husking process. When the mouth was closed the lateral palatine groove was enclosed in the lower beak and helped in holding the seed (McLelland, 1979) [27]. Hard palate at its posterior one-third part the infundibular cleft was observed in the form of an elongated oval depression and consist of a wide posterior part and the anterior part was narrow. The anterior and the posterior part of infundibular cleft was separated by two transverse ridges in ducks, three transverse ridges in turkey and Japanese quail and no ridges in chicken (Igwebuike and Anagor, 2013) [16]. The lumen inside the infundibular cleft divides the cleft in to right and left by the median ridge with their respective communication to right and left nasal cavities. The number of posteriorly directed transverse row of papillae were 4-6 in turkey, 4-5 in chicken and 3-4 in Japanese quail were observed at the posterior part of the infundibular cleft. The infundibular slit continues with choanal slit anteriorly and laryngeal opening posteriorly and was observed on the middle of the roof of the oropharyngeal areas as a median longitudinal fissure with common opening of the two eustachian tubes. (King and McLelland., 1984) [23]. The infundibular slit length was recorded as 0.6 cm in Turkey, 0.4 cm in Chicken and 0.2 cm in Japanese quail respectively. In turkey and Japanese quail, the rim of infundibular slit was composed of short papillae and the infundibular slit was deeper than the choanal slit and the anterior and posterior commissures were wider when compared to the choanal slit (Rajathi, 2020) [34]. No median union of the orbital folds in birds were observed (McLelland, 1979) [27]. The roof of the mouth has a palatine cleft, it is due to the paired pharyngeal fold remain separate throughout their entire length, and is less wide at its apical end and wider at its posterior part. (McLelland, 1990) [26]. Palatine cleft is large in fowl and pigeon and small in duck and goose. Palatine cleft is the communication between the oral and the nasal cavities in birds (McLelland, 1979) [27].

In birds in between the oral and the pharyngeal cavities the palatine cleft is broader. Pharyngeal folds are separated by a narrow, transverse bridge of mucous membrane and terminates at the infundibular cleft (McLelland, 1979) [27]. Roof of the pharynx is composed of infundibular cleft, leads into the dilated tubopharyngeal space, which is the opening of the auditory tubes observed at the base of the skull (Nickel *et al.*, 1977) [31].

Floor of the oropharyngeal cavity

Salivary Gland

The hard palate is composed of salivary glands in the mucous membrane. At the end of the palatine cleft in the incisivum bone a flat maxillary gland is present. A collecting duct is present throughout the length of the gland and around these glands is mucous terminal cells are grouped in the form of lobules. The efferent ducts are short and terminate bilaterally in the anterior region of the hard palate (McLelland, 1979) [27]. The lateral palatine glands are multilobular and are lateral to the lateral ridges in location in the fowl with numerous efferent ducts terminate in this region. Around the palatine cleft, medial palatine gland tubules are situated and others are posterior to it (King and McLelland., 1984) [23]. The numerous efferent ducts opening and its distribution indicates the extent of the glands. The mucosa of the roof of the pharynx consists of the tubariae gland and pterygoid gland. The pterygoid gland was superficial and open their efferent ducts, at the sides to the infundibular cleft. whereas the tubariae gland are located at the place where the ducts open, the auditory tubes (Sisson and Grossman 1955) [39]. The angle of the lower beak at its anterior part consists of anterior mandibular gland in the floor of the oropharyngeal cavity and three groups of posterior mandibular gland in the fowl was observed (Dyce *et al.*, 2002) [5]. The mucosa of the angle of the oropharyngeal cavity has anguli oris gland with single efferent duct. The mucosa of auditory tube is composed of more lymphoreticular tissue. Lymph follicles, in the form of tubal tonsils, are more in the goose than that of pigeon.

The oropharynx floor was formed between the rami and consists of the tongue and the laryngeal mound. In between the rami is a triangular region which accommodated the two rami of mandible forming the oropharynx as reported by (Rodrigues *et al* 2012) [36] in rhea and (Nickel *et al* 1977) [31] in other domestic birds (Gupta *et al.*, 2015) [10].

Tongue

The tongue is firmly fixed to the roof of the oropharyngeal cavity at the time of respiration and closes the choanal cleft at its narrow part and broader posterior part allow air entering the larynx (Nickel *et al.*, 1977) [31]. The variation in the size and structure of birds tongue is mainly due to the functional requirements of different species (Nickel *et al.*, 1977) [31]. The tongue of birds is triangular in shape and fits to the lower beak, in galliform (Iwasaki and Kobayashi, 1986 [24]; Homberger and Meyers, 1989 [13]; Dehkordi *et al.*, 2010; Jackowiak *et al.*, 2010 [21]; Parchami *et al.*, 2010 [33]; Erdogan and Alan, 2012) [8]. Avian tongue, the lamina propria, submucosa and hyaline cartilage (entoglossum) has high distribution of lingual glands except at the tip of the tongue (Hodges, 1974 [12]; King and McLelland, 1984 [23]; Samar *et al.*, 2002) [37-38]. The wide and triangular shaped tongue of Galliformes birds whereas in pigeon the tongue was narrow and are well differentiated from the pharynx in the floor of the oropharangeal cavity by the posteriorly arranged papillae in a transverse row as reported in ostrich (Tadjalli *et al.*, 2008) [41]. The faint median groove and many transverse grooves helps in differentiating dorsal surface. The tongue was highly convex and wide, scalpel shaped and will not reach the full length of the lower beak and also marked by a median ridge ventrally as reported by (Kadhim *et al.*, 2011) [22] in Red jungle fowl (Nickel *et al.*, 1977) [31]. Regurgitation is prevented by the length and width of tongue which allows the feed to go in one direction that is towards the esophagus (McLelland, 1979) [27]. The tongue of lamellirostres completely fills the floor of the oropharyngeal cavity and is only slightly narrow in front. The entoglossum forms the body of the tongue and unites with the basihyoid bone in forming a movable joint and ends anteriorly in a cartilaginous process and lies at the bottom of the tongue. The mammalian tongue is composed of muscle system internally whereas in avian tongue there is no muscle system internally only the anterior third is free of musculature and the extralingual muscles seen on the posterior parts of the tongue and is also composed of connective and adipose tissue and insinuated glands (Dyce *et al.*, 2002) [5]. The frenulum linguae to the tip of the tongue gives the total length of the organ and forms the large part of the sublingual and prefrenular part of the floor of the oropharyngeal cavity. The dorsum of the tongue at its anterior region was heavily keratinized mucous membrane (McLelland, 1979) [27]. The base of the tongue at its lateral surfaces and lower surfaces, the stratum corneum was moderately thick. At the edges of the tongue in duck and goose, apart from the row of lingual papillae some horny papillae are located just above the lingual papillae in separate row (McLelland, 1990) [26]. These horny papillae are pointed and thorn like placed in between the thread like lingual papillae near the pharynx and it acts like a filter on either sides of the beak (King and McLelland., 1984) [23]..

The lingual glands were grouped by Ziswiler and Farner (1972) into, the superior and inferior lingual glands. (Erdogan *et al.*, 2012) [8], the lingual glands have been classified as anterior and posterior glands whereas in the quail, Liman *et al.* (2001) [25] the lingual, preglottal and laryngeal glands were present, and Capacchietti *et al.* (2009) [2] referred to anterior and posterior lingual glands in the chicken (Hodges, 1974 [12]; Nickel *et al.*, 1977) [31]. At the base of the tongue the posterior lingual glands are located and are extend to the larynx.

Lingual papillae variations play a crucial part in bird feeding as a structure that resembles teeth in the upper and lower beaks. Lingual apparatus in birds have various chemical properties related to the feeding habits. The papillae are absent in the tongue of birds whereas, taste buds are present in singly or in groups and opens around the ducts of the glands (McLelland, 1979) [27]. Taste buds are mainly noticed in the base of the tongue and at the mucosa of the pharynx to the anterior portion of the oesophagus.

The pharynx forms the posterior part of mouth cavity. The length of the upper parts of the pharynx was 1.57±0.04 cm and lower parts of the pharynx was 2.29±0.08 cm, respectively. The width of anterior regions of upper part of the pharynx was 1.51±0.02 cm and posterior regions of upper part of the pharynx was 0.69±0.05 cm, respectively, while these parameters for width of anterior regions of the lower part of the pharynx were 1.17±0.03 cm and posterior regions of lower part of the pharynx was 1.46±0.05 cm, respectively.

The posterior limit of pharynx on upper part had single row of papillae, while the lower part had two rows of papillae. In red jungle fowl the pharyngeal papillae were arranged in a single row behind the laryngeal cleft (Kadhim *et al* 2011) [22].

The posterior part in the centre of the tongue a mucosal swelling, the laryngeal mound, was present in fowl as reported by (Igwebuike and Eze 2010) [14-17] in African pied crow. The length of the laryngeal mound was 1.09±0.03 cm and 0.56±0.02 cm long with the glottis on the anterior surface. The mucous membrane of the laryngeal mound was marked with the two rows of posteriorly directed papillae (Gupta *et al.*, 2015) [10].

Articulations

Both the lower and upper jaws move when the oropharyngeal cavity is opened, hinge articulation of the lower jaw is formed by the quadrate bone at the base of the jaw, the hinge between the frontal and nasal bones provides flexibility in upper jaw. The quadrate bone moves forward on its articulation with the cranium as the lower jaw moves downward, this action moves the bones of the hard palate, below the eye to the maxilla and reach the main bone of the upper jaw (McLelland., 1990) [26].

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