



Research Article

Comparative Anatomical, Radiological and Computed Tomography Studies on the Quadrate Bone (Os Quadratum) in Ducks (*Anas Domesticus*) and Ibis (*Bubulcus Ibis*)

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ABSTRACT

Concerning to exhibit the key morphological variation between the quadrate bone in duck (mixed food eating bird) and Ibis (carnivorous bird), our study was performed on twenty adult duck (*Anas domesticus*) and Ibis (*Bubulcus ibis*) of both sexes. The birds heads were radiographically examined, Computed Tomographic (CT) studied, carefully dissected, described and compared. Also, the bones were prepared and measured. The gross morphological study showed that the quadrate bone in both species, was present between the upper bill and the mandible, it consisted of body and three processes; mandibular, otic and orbital. The body was star shape in duck and molar tooth-like in ibis. Cotyla quadratojugalis was present on the root, on the lateral aspect of lateral condyle in duck and ibis respectively. Condylus rostralis and Sulcus intercondylaris medialis was present in ibis only. The medial condyle was elongated in duck and heart-shape in ibis. The lateral jugalm and ibular ligament was a broad, thick, terminated in the lateral cotyla and the dorsal border of the mandible in duck and ibis respectively. Radiological examination and Computed tomographic imaging of the quadrate bone was made for evaluation topographic anatomy of the bone. The results were discussed for better understanding the differences in shape, size, site and ligamental attachments between the two birds which may be correlated with the difference in feeding habits.

Key words: Quadrate bone, duck, Ibis, Otic processes, Cotyla quadratojugalis and Jugalmandibular ligament.

INTRODUCTION

Poultry considered an essential source of animal proteins for human health (Mohamed, 1989). The major importance of ibis to farmers as it feeds on a wide range of prey, particularly insects moths, spiders, and frogs, as well as earthworms (Seedikkoy *et al.*, 2007) The role of this bird in the management of insect pests in different agro-ecosystems is also reported by Yadav (2000).

The cranial kinesis; controlled the jaws, amplified the ability of feed selectively, shock absorbance, improved speed of opening and closing of the bills and concentrated the force necessary to open the bills (Bout and Zweers, 2001; Gurd, 2006; Gurd, 2007; Estrella and Masero, 2007). The quadrate is a keystone of quadrato-squamosal joint this makes its cranial kinematics of great interest. Hence, it elevated the upper bill by rotation the joint rostrally, dorsally and slightly medially respectively. Then transmitting this force to jugal and the mobile pterygoid-palatine complex, pushing on the upper bill and elevated it (Zusi, 1984; Bout and Zweers, 2001; Gussekloo,

Vosselman and Bout 2001; Gurd, 2006; Gurd, 2007; Estrella and Masero, 2007). So, our study is a trial to reveal the differences in the gross anatomical characteristic features between the quadrate bone of duck as mixed food eating bird and Ibis as a carnivorous bird. Such information is important to understand the different mechanisms of feeding and drinking habits.

MATERIALS AND METHODS

The present work was carried out on ten heads of each adult duck and ibis of different species of both sexes which were collected from the Zagazig villages and hunted from the fields Sharkia governorate, Egypt respectively. Four specimens of each species were freshly dissected to clarify the gross anatomical features of the quadrate bone and its ligaments attachment. Two specimens of each bird were prepared as a bone preparation to describe the anatomical features of the articular surfaces of quadrate bone with the surrounding structures by maceration method according to Onwuama,

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Salami, Ali, and Nzalak (2012). The latter six specimens also were used to reveal the anatomical morphometry by using stainless Caliper and flexible meter. Two specimens were used for radiological examination, dorsolateral views were taken with the closed bill at 40 KV and 10mAs in both birds in the surgery department in the faculty of veterinary medicine, Zagazig University. Computed tomographic (CT) studies were done on two birds of each species; the heads were undergone consecutive CT scan using at AL-Bayan center in Belbes, Sharkia Governorate, Egypt. The latter two specimens also were sectioned transversally just rostral to the external acoustic meatus in duck and at the level of zygomatic process in ibis. Dissected samples were photographed by Nikon digital camera with resolution (16.1 megapixels, Sony DSC-W690, 36v, and 10x optical zoom). The anatomical nomenclature terms used in this study was adopted according to (Nomina Anatomica Avium, 1993). All obtained birds kept under observation for two weeks before the experiment and received proper care according to the Ethics of Animals Use in Research Committee (EAURC), Zagazig University with approval number (ZU-IACUC/2/F/93/2018).

RESULTS

This work revealed that the quadrate bone (Os quadratum) was present in between the upper bill and the mandible. It was large star shape in duck and small molar tooth-like in ibis. It consisted of the body (corpus ossis quadrati) and three processes; mandibular (Proc. mandibularis), orbital (Proc. Orbitalis quadrati) and otic (Proc. oticus quadrati). (Figs. 1, 2, 3, 4, 5 and 6).

Proc. Os quadratum:

Proc. mandibularis quadrati was the most developed especially in ibis. It possessed three articular condyles; lateral (Condylus lateralis), medial (Condylus medialis) and caudal (Condylus caudalis), articulate with the corresponding cotyla of the mandible. The three condyles in duck were arranged in a right angle triangle while in ibis were equal border triangle (Figs. 7-10).

Condylus lateralis was the most cranial one, articulated ventrally with the lateral cotyla of the mandible. It was elongated, wide, in duck but in ibis was oval in shape. The root of lateral condyle bore Cotyla quadratojugalis in duck while in ibis it was present on the lateral aspect for articulation with Condylus quaadraticus of os quadratojugale. The lateral condyle possessed an additional condyle (Condylus rostralis) on its rostral surface in ibis. The articular surface of the lateral condyle was convexly measured about the 0.5cm length and 0.3 cm width in duck and in ibis about 0.3 cm. length and 0.2 cm width (Figs. 11-17).

Condylus medalis was located cranioventrally, articulated with the medial cotyla of the mandible. It was elongated deeply convex in duck and well-developed heart-shape in ibis. It carried rostromedially a rounded, convex articular facet (Condylus pterygoideus) for articulation with the distal end of Os pterygoideum. The articular surface of the medial condyle about 0.4 cm, 0.3 cm length, and 2.4mm, 4mm width in duck and ibis respectively. The lateral and medial condyles were

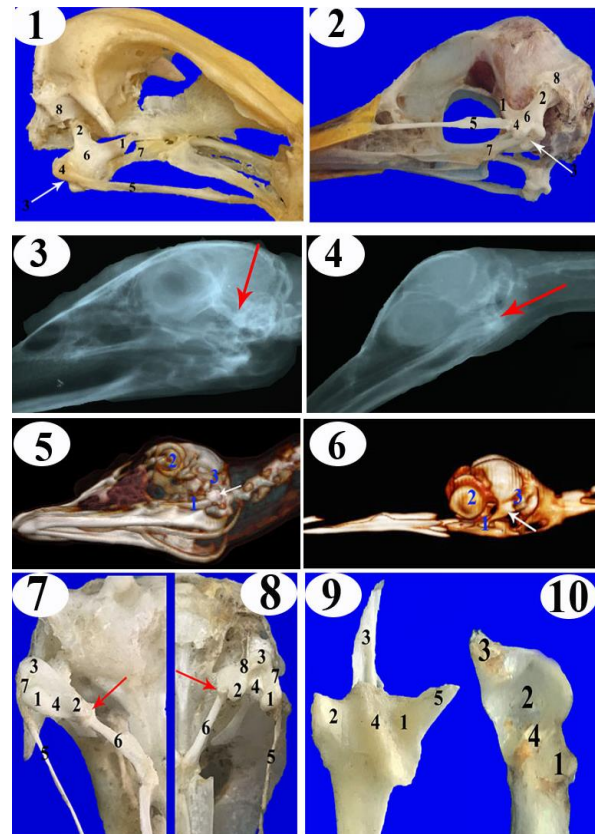


Fig. 1-10: Photomicrographs of the duck skull (1) right side, lateral view and Ibis (2), left side ventrolateral view respectively showing: 1-Proc. orbitalis quadrati, 2- Proc.oticus quadrati, 3-Proc. Mandibularis quadrati, 4-Os quadratojugale, 5-Os jugale, 6-corpus Quadratum,7- Os pterygoideum and 8- Os Temporale. Photoradiographs of duck (3) and Ibis (4) head with closed mouth, left dorsolateral view showing the quadrate bone articulation red arrow. Photomicrographs of 3D computed tomography (CT) of duck (5) and Ibis (6) head left side showing the quadrate bone articulation: 1-Os jugale, 2-eye, 3-ear and corpus Quadratum (white arrow). Photomicrographs of sagittal section of the skull of duck (7) and Ibis (8) ventral view showing 1-Condylus lateralis,2-Condylus medialis, 3- Condylus caudalis 4-Sulcus intercondylaris rostralis, 5- Os jugalis, 6-Os pterygoideum, 7-Sulcus intercondylaris lateralis, 8- Sulcus intercondylaris medialis and Condylus pterygoideus (red arrow). Photomicrographs of articular end of the mandible in duck (9) and Ibis (10) dorsal view showing:1- Cotyla medialis, 2- Cotyla lateralis, 3- Proc. retroarticularis,4- Tuberculum intercotylare (Crista intercotylaris) and 5- Proc. medialis mandibulae.

separated rostroventrally by a large intercondylar groove (Sulcus intercondylaris rostralis) which was oblique in duck and straight in ibis for articulation with an intercotylar ridge (Crista intercotylaris) of the mandible (Figs. 11-17).

Condylus caudalis (Proc. postmandibularis) projected toward the rear. It was separated from the lateral and medial condyles of the mandibular process by Sulcus intercondylaris lateralis and Sulcus intercondylaris medialis respectively in ibis. Sulcus intercondylaris medialis was absent in duck. It was measured about 0.4 cm in length and 0.3 cm in width in duck and 0.2cm in length and about 0.3 cm in width in ibis (Figs. 11-17).

The orbital process of the quadrate bone in both species was the most craniodorsal one which extended medially toward the orbit to end freely in musculature.

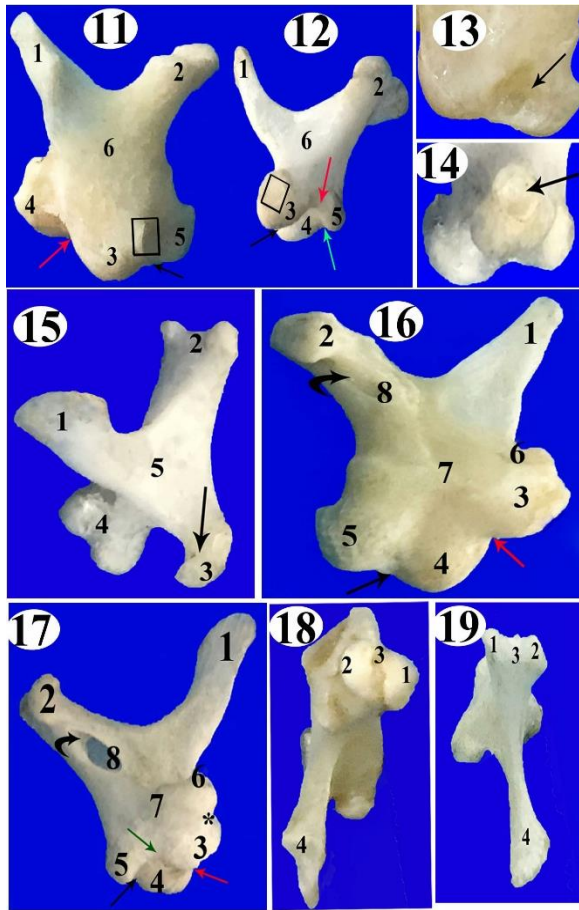


Fig. 11-19: Photomicrograph of the lateral surface of separated quadrate bone of the duck (11) and Ibis (12) showing: 1- Proc. Orbitalis quadrati, 2- Proc.oticus quadrati, 3- Condylus lateralis, 4- Condylus medialis, 5- Condylus caudalis, 6- corpus quadratum, Sulcus intercondylaris rostralis (Black arrow), Sulcus intercondylaris lateralis (Red arrow) and Sulcus intercondylaris medialis (green arrow). Higher magnification of pervious inset of separated distal end of quadrate bone of the duck (13) and Ibis (14) lateral view of the lateral Condyle showing Cotyla quadratojugalis (black arrow). Photomicrograph of the anteriodorsolateral view of separated quadrate bone of the Ibis (Fig.15) showing: 1- Proc. Orbitalis quadrati, 2- Proc.oticus quadrati, 3- Condylus lateralis, 4- Condylus medialis, 5- corpus quadratum, and condylus rostralis (black arrow). Photomicrographs of the medial surface of the quadrate bone of the duck (16) and Ibis (17) showing: 1- Proc. Orbitalis quadrati, 2- Proc.oticus quadrati, 3- Condylus medialis, 4- Condylus lateralis, 5- Condylus caudalis, 6- Condylus pterygoideus, 7- corpus quadratum, 8- Foramen pneumaticum, Sulcus pneumaticus (curved arrow), Sulcus intercondylaris rostralis (Red arrow) and Sulcus intercondylaris lateralis (Black arrow), Sulcus intercondylaris medialis (green arrow) and Incisura intercondylaris (*). Photomicrograph of the anteriodorsal view of otic process of quadrate bone in the duck (18) and Ibis (19) showing: 1- lateral capitula, 2- medial capitula, 3- Incisura intercapitularis and Proc. Orbitalis quadrati (4).

This process was elongated, convex laterally and concave medially. The lateral surface of this process carried a tubercle in duck. This process had a pointed summit in duck while in ibis had a broad end (Figs. 1, 2, 11, 12, 16 and 17).

The otic process of the quadrate bone in both species jointed with Os temporale by means of two capitula (lateral squamosal and medial otic) which was separated

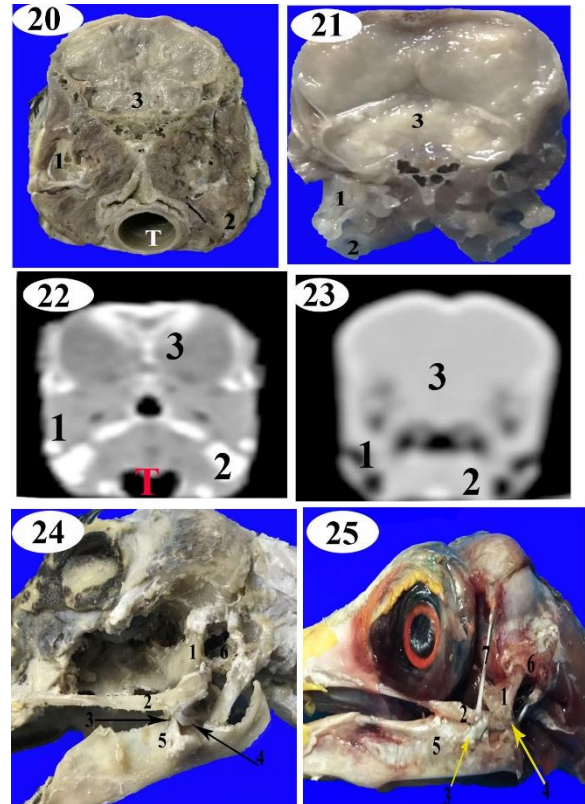


Fig. 20-25: Photomicrograph of formalized head (cross section) and computed tomography CT (coronal section) of the duck (20, 22) rostral to the external acoustic meatus and Ibis (21, 23) at the level of zygomatic process (caudal view) respectively, showing: 1- corpus ossis quadrati, 2- Ramus mandibulae 3- brain, and T- Trachea. Photomicrographs of the duck head (24) and Ibis (25) (left lateral view) showing: 1- Corpus quadratum, 2 - Os jugalis, 3- Ligamentum jugomandibularis lateralis, 4- Ligamentum jugomandibularis medialis, 5- Ramus mandibulae 6- Meatus acusticus externus. 7- Ligamentum supraorbitale.

by a clear Incisura intercapitularis. The medial capitulum was larger in duck wherever in ibis the two capitula were equal and oblique resemble a trochlea. The medial surface of this process in both species possessed an oval pneumatic foramen (Foramen pneumaticum) which continued caudomedially by a groove (Sulcus pneumaticus). The foramen is wider in ibis than duck. the otic process had a cranial tubercle for muscular attachment in duck. The process with the upper body of the quadrate bone forms the rostral boundary of the tympanic cavity (Figs. 1, 2, 11, 12, 16, 17, 18 and 19).

Corpus Os quadratum:

The body of quadrate bone had two surfaces (lateral and medial) in both species, four borders (rostral, caudal, dorsal and ventral) in duck and three in ibis that lacks the ventral one. In both species, the lateral surface was flat and smooth. The medial surface was convex and irregular in duck and concavoconvex from cranial to caudal in ibis. The rostral border was extended from the orbital process to medial condyle of the mandibular process in duck but in ibis ended in mandibular process. The caudal border was present between the otic process and caudal condyle in both species. The dorsal border was between the orbital and otic processes in both species. The ventral border was situated between medial condyle of the mandibular

process and caudal condyle in duck. The Craniocaudal axis started from the orbital process to the caudal condyle with average about 1.08 cm and 1.18 cm in duck and ibis respectively. Caudoventral axis extended from otic process to medial condyle of the mandibular process with average 1.85 in duck and 1.02 in ibis. Dorsoventral axis began from dorsal border of the body to lateral condyle of the mandibular process with average about, 1.82 in duck and 0.62 in ibis (Figs. 11, 12, 16, 17, 20, 21, 22 and 23).

Ligamentus attachment of Os quadratum:

Lig. Jugomandibularis lateralis (lateral Jugomandibular ligament) in duck was broad triangular band attached dorsally to the rostral surface of the lateral condyle of quadrate bone and under Os quadratojugal ventromedially, then descended ventrally to terminate on the lateral cotyla of the mandible. It measured about 1cm average in length and about 0.7cm average in width (Fig. 24). While in ibis it was a short thick fibrous band began from the lateral aspect of the lateral condyle crossing over Os quadratojugal and the rostral end of the medial quadratomandibular ligament. After that descended rostroventrally to attach the dorsolateral border of the mandible, about 0.4cm average in length and 0.2cm average in width (Fig. 25). *Lig. Jugomandibularis medialis* (medial Jugomandibular ligament) in duck was a thin fibrous band extended from the ventrolateral edge of Os quadratojugal and the lateral aspect of lateral condyle of the quadrate. It curved caudomedially to join the dorsal border of the rostral end of the retroarticular process. Then it crossed the articular surface of the mandible to be attached to the caudal border of the medial process of the mandible just caudal to the medial cotyla. It measured about 1 cm average in length and about 0.7cm average in width (Fig. 24). However, in Ibis, this ligament was a long thin band initiated from the lateral aspect of the lateral condyle of quadrate bone and caudodistal end of Os quadratojugal. It extended caudolaterally on the ventral margin of the quadrate bone laterally to end in the lateral cotyla of the mandible caudally. It measured about 0.6cm average in length and 0.2cm average in width (Fig. 25). The angle between the upper and lower bill was wider in ibis than duck. The great extent of mouth opening in duck was average about 5.2 cm and in ibis was average about 5.8 cm.

DISCUSSION

Our results affirmed that the quadrate bone was complex bone-in duck and ibis not only connect the skull to the mandible forming the quadratum and ibular joint (that homologous temporomandibular joint in mammals) but also was the pivotal bone of cranial kinesis (Feduccia (1975). This work clarified that the quadrate bone was placed between the mandible ventrally, caudal part of the quadratojugal laterally, pterygoid bone rostrorodorsally, squamous and basisphenoid bones caudodorsally. The pervious quadrate articulation in both duck and ibis were parallel to that established in other domestic and wild birds as stated by King and McLelland (1975); Vandenberg (1975); Nickel *et al.*, (1977); Baumel (1979), MacLelland (1990); Kent and Car (2001); Dyce *et al.*,

(2002), Dawson *et al.*, 2011 in duck and Ali (2015) in ostrich.

The three processes of the quadrate bone were found in fowl, duck, geese, pigeon, Hooded crow and Cattle egret (Feduccia, 1975, King and McLelland, 1984, Shevily, 1987 and Hassan, 2012). The orbital process of the quadrate bone was directed toward the orbit for muscular attachment (Chaisson, 1984 in pigeon, Imam and Elmahdy 2004 in ostrich and Hassan, 2012 in Hooded crow and Cattle egret). It was elongated in duck similar to that of pigeon (Chaisson, 1984), Hooded crow and Cattle egret (Hassan, 2012). on the other hand, this process had a pointed end in duck while in ibis was broad free end like in ostrich (Imam and El mahdy 2004 and Ali 2015). Moreover, in duck lateral surface of the orbital process carried a tubercle for muscular attachment while smooth in ibis. In most neognaths, the quadrate had a bicondylar well-defined articulation with the squamosal (Cracraft, 1986; Elzanowski, Paul, and Stidham, 2000). our work clarified that the two capitula of the otic process were unequal in duck but in ibis they were equal and the pneumatic foramen was wider. The presbyornithid quadrates had numerous caudomedial pneumatic foramina while in the Anhimidae (episode) marked by the presence of individual pneumatic foramen (Elzanowski and Stidham 2010). Zweers (1974) in the mallard duck, revealed that the two condyles of the otic process were oriented mediolaterally and with a slight rostrocaudal. The otic process had a tubercle cranio-laterally in a duck for muscular attachment. On the contrary with ostrich (Imam and Elmahdy 2004 and Ali 2015), the mandibular process of the quadrate bone in both duck and ibis had three condyles similar to that reported by Imam and Elmahdy (2004) in flamingo and (Hassan, 2012) in Hooded crow and Cattle egret. The lateral condyle of the mandibular process was elongated, wide in duck but oval in ibis. The Cotyla quadratojugal is present on the root of lateral condyle in duck resembling ostrich (Imam and Elmahdy 2004 and Ali 2015). Whereas in ibis Cotyla quadratojugal is present on the lateral aspect of lateral condyle as in Hooded crow and Cattle egret (Hassan, 2012). The medial condyle of the mandibular process was elongated deeply convex in duck and well-developed heart shape in ibis due to the presence of incisura intercondylaris. Sulcus intercondylaris medialis and incisura intercondylaris of the caudal condyle were present in ibis only.

our study recorded that the quadrate bone was fixed by Lig. Jugomandibularis lateralis et medialis in both duck and ibis which is online with (Hassan, 2012) in Hooded crow and Cattle egret. Regarding measurements of the ligaments and the angle between two the bills revealing that the ibis can open their mouth more than duck which enables it feeding a wide range of prey reaches to frogs (Seedikkoy *et al.*, 2007).

Conclusions

There were many differences in the gross anatomical characteristic features between the quadrate bone of duck as mixed food eating bird and Ibis as a carnivorous bird. So, we can understand the different mechanisms of feeding and drinking habits of both species.

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