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Research Article

Computerized Tomography, Radiological and Morphological Features on the Skull of Egyptian Owl (*Bubo ascalaphus*)

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Abstract | This study was applied on the Skull of Egyptian Owls, using X-ray and computed tomography (CT) to recognize possible clinical affections of skull and provide clear anatomical data through anatomical dissection. The specimens of six carcasses were carried out to department of anatomy, Faculty of veterinary medicine, Cairo University. Four heads were dissected for morphological study and X-ray, other two specimens accommodated to CT. The skull of owl constructed mainly from the neurocranium, viscerocranium and the mandible. The cranial bone used for housing the brain; comprised of frontal, parietal, occipital, sphenoid and temporal bone while the bones of face formed of nasal, quadrate bone, zygomatic, palatine, vomer, premaxillary, maxillary and ethmoid. The cranium and viscerocranium demarcated from each other by orbital cavities. The mandible composed of five ill distinguished bones; dental, splenial, angular, supra angular, and the articular.

Keywords | Egyptian owl, Skull, Morphology, Radiology, Computerized tomography

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INTRODUCTION

Owl is a nocturnal predator bird that belongs to family *Strigidae* (*Strigiformes*), they are different in size and habitation, in Egypt it known as Pharaoh Owl. They are usually active at night and have well developed auditory system, their ears covered by feathers of the facial disc. Some species have asymmetrical ear openings and a very distinct facial disc (Nishikawa, 2002). In agricultural regions Owls afford benefits to humans by killing large number of rodents (Konig, 1999). They are anatomically closely related with other nocturnal predator bird as falcon and hawks (Hackett et al., 2008). The skeletal system is reformed according to different habitat, survivability among various species (Kumar et al., 2016), especially morphological adaptations of the skull between different species. The main differences are in the orbital and the otical region, which are associated with the visual and hearing abilities (Pecsics et al., 2018). We attend to provide more anatomical information on the bony structure which is important to zoologists for taxonomic and phylogenetic reasons (Süzer et al., 2018). Moreover, it aids veterinarians in understanding the interpretation of X-ray images that necessary in dealing with wild bird's surgical affections especially in cranium. The skull of Owl has many biological roles, including feeding, grooming, nest-building and defense, so that our study will help in understanding the different physiological habits and to illustrate the functional anatomy of feeding apparatus that differ according to environmental requirements (Tibor et al., 2017).

MATERIALS AND METHODS

This work was approved by the Institutional Animal Care and Use Committee at Faculty of Veterinary Medicine, Cairo University, Egypt. Also, all international guidelines for animal care and use were followed up.

Animals six carcasses of owls were used in this study; they were carried out from Giza Zoo Park to the Department of anatomy in veterinary medicine, Cairo University.

Radiological and Anatomical study, four heads were exposed to beam lighting X-ray device of exposure factors 100 cm, FFD with 15 mAs and 100 KV. The specimens placed in dorsoventral and lateral direction. After that the heads separated from the whole body then macerated by boiling maceration technique using sodium bicarbonate powder and boiled water; the specimens were checked every 10 minutes with manual removal of tissue from it. Finally the bone samples were bleached using hydrogen peroxide solution for 10-15 minutes then dried for morphological demonstration (Fenton et al., 2003).

Computed Tomography (CT), two specimens were used for CT scan using Hitachi- hyperdense well-defined on CT images CXR 4 Multi-Slice CT Scanner. The heads maintained in lateral and ventral positions. The Computed tomography performed at 130 kilovolts and 80 mAs with continuous transverse series obtained every 5-6 mm.

RESULTS AND DISCUSSION

The skull of owl formed mainly from the cranium (Figures 1A, 1B and 2A) or cranial bones (caudal part) for housing the brain, the viscerocranium (cranial part) involves the bones of the face and the mandible (Figure 6A and B). The caudal part comprised of occipital, parietal, frontal, sphenoid and temporal bone while the cranial part formed of, nasal, quadrate bone, jugal (zygomatic), palatine, vomer, pterygoid, premaxillary, maxillary and ethmoid. Both regions demarcated from each other by the orbital cavities.

Cranium (neurocranium)

Occipital bones (Figures 1A, 3A, 3B, 4B and 5A\1) established the caudal part of skull; formed by three parts; squamous part also known as supraoccipital (Figure 1A and 2A\1a) form the dorsal boundary of the rounded foramen magnum (Figures 1A, 2A and 5A\FM), basioccipital part (Figures 1A and 2A\1b) which ventral to the occipital condoyle (Figures 1A and 2A\1d) and paired exooccipital ones (Figures 1A and 2A\1c). The Occipital condoyle was single and rounded with dorsal median notch (Figures 1A and 2A/1d).

Parietal bones (Figure 1A, 1B, 3A and 3B\2) were thin bony plates, deliberated the most caudal part of dorsum of the cranium; it separated from the supraoccipital bone by the curved ill distinct nuchal crest (Figure 2A\N). The demarcated suture between parietal and frontal bone was not clear due to the fusion between them.

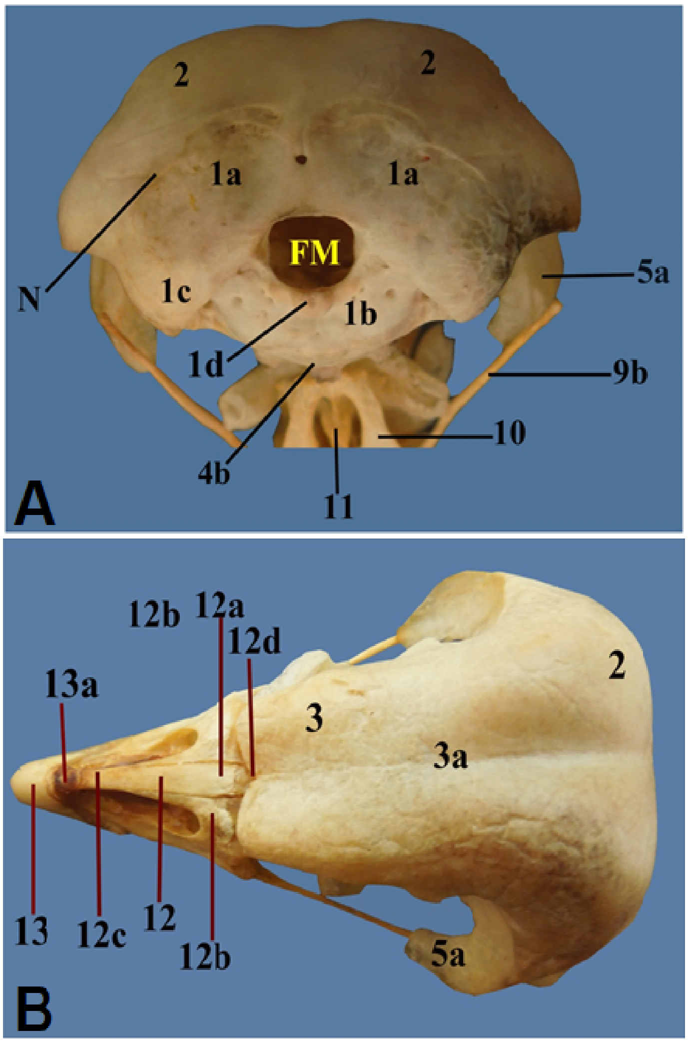

Figure 1: A photograph showing; (A) Occipital region of cranium; (B) Dorsal aspect of cranium.

Frontal bones (Figures 1B, 3A, 3B, 4B and 5C\3) considered the largest bone forming rostral part of roof of the cranium, its external surface of both sides has shallow longitudinal groove (Figure 1B\3a) in-between, while the orbital surface formed the medial boundary of the orbit, that fused together forming the inter-orbital septum.

Sphenoid bone chiefly formed the floor of cranium. It made of two parts, first part was presphenoid (Figure 2A\4a) which has a small narrow part that combined rostrally with vomer bone and laterally it carries two oval facets for pterygoid bones (Figure 2A\PT). Second part was basisphenoid (Figures 1A and 2A\4b) which has a large, wide posterior part which was united caudally to basioccipital bone.

Links Researchers

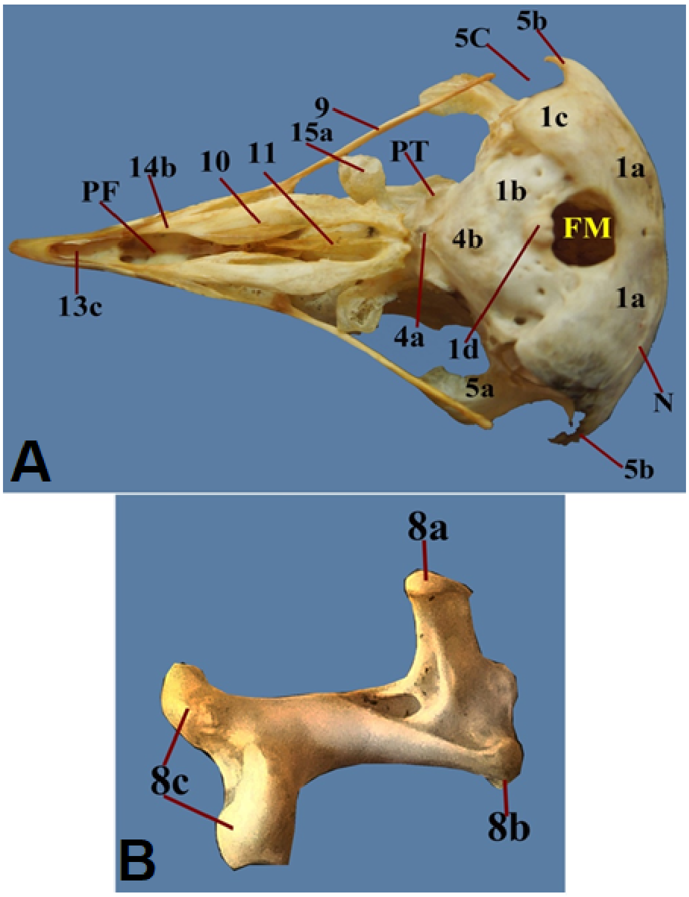

Figure 2: A photograph showing; (A) Ventral aspect of cranium; (B) Quadrate bone.

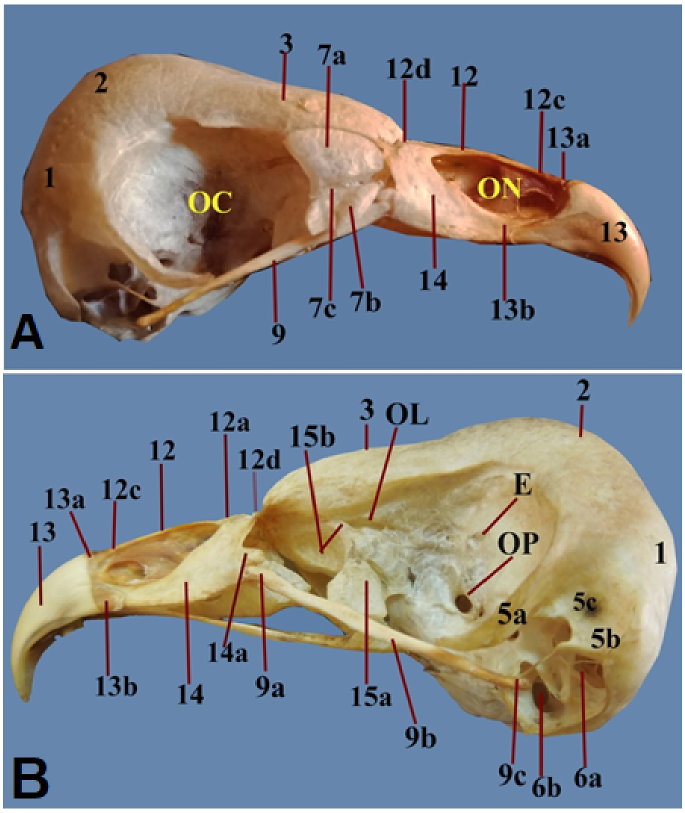

Figure 3: A photograph showing lateral aspect of cranium. (A) before removing lacrimal bone; (B) After removing lacrimal bone.

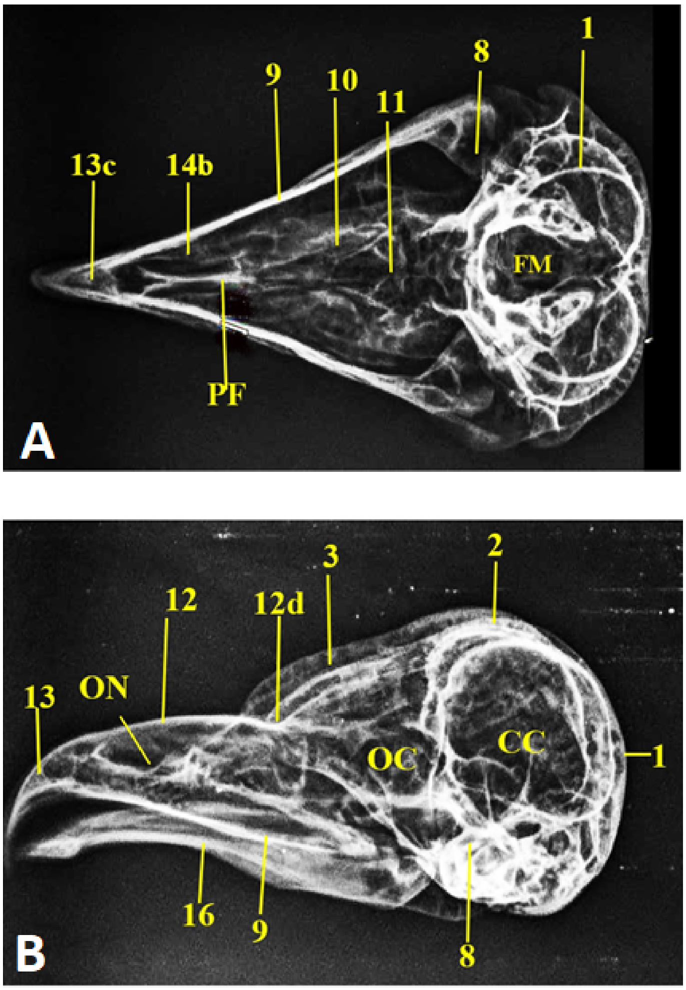

Figure 4: A photograph showing X-ray image of whole skull; (A) Ventral view; (B) Lateral view.

Temporal bone consisted of squamous part and ear capsule. The squamous part shared in construction of the lateral wall of the cranium. It had a fairly long, flat orbital process (Figures 1A, B, 2A and 3B\5a) just cranial to the temporal fossa (Figures 2A and 3B\5c) and small zygomatic process (Figures 2A and 3B\5b). The ear capsule was an oval cavity which contained internally two cavities the dorsal is the external acoustic meatus (Figure 3B\6a), while the ventral one is the tympanic cavity proper (Figure 3B\6b).

The viscerocranium

Nasal bone (Figures 1B, 3A, 3B, 4B and 5C\12) was thin, flat bone formed mostly the dorsal boundary of the nasal cavity and part of the upper beak. It has three processes; frontal process, premaxillary process and maxillary process. The frontal process (Figures 1B and 2B\12a) joined the frontal bone through Frontonasal hinge (Figures 1B, 3A, 3B, 4B and 5C/12d) as a movable joint between those bones. The maxillary process (Figure 2B\12b) passed ventrolaterally to join the maxillary bone. The premaxillary process of nasal (Figures 2B, 3A and 3B\12c) connected to premaxillary bone forming the roof of external opening of the nostrils (Figure 3A, 4B and 5C/ON).

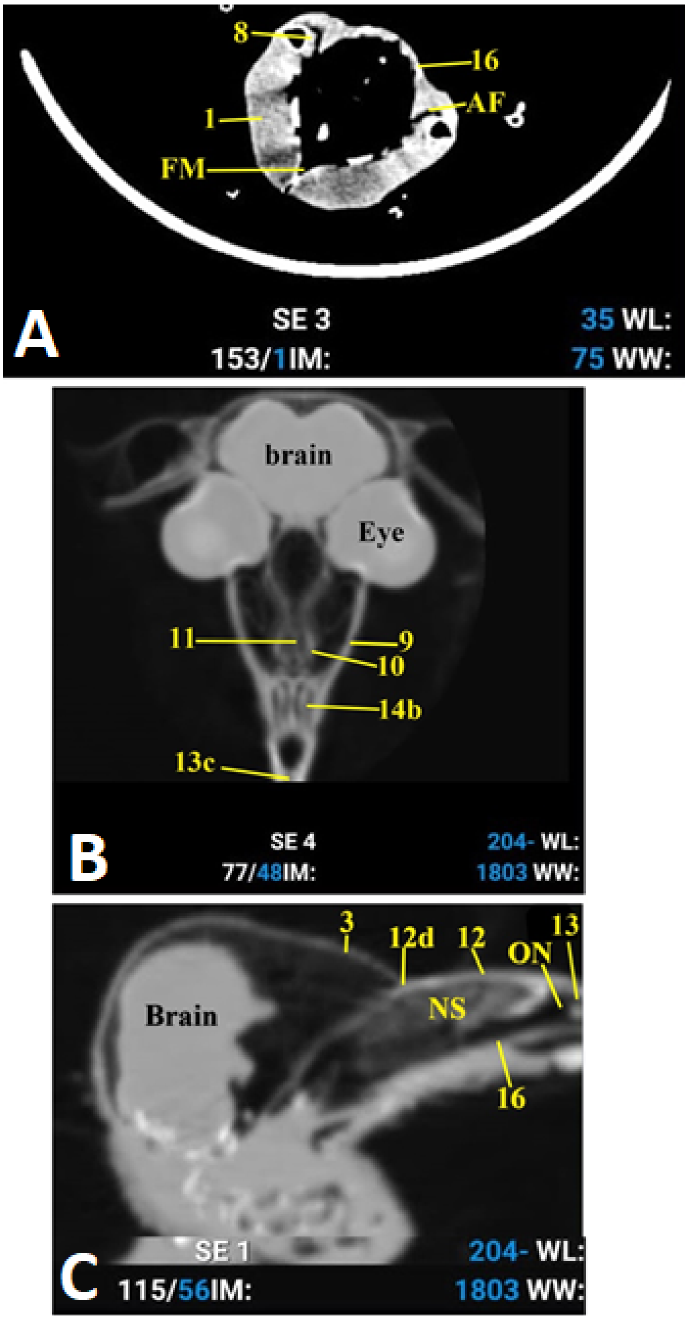

Figure 5: A photograph showing CT image of whole skull. A: caudal view; B: Ventral view; C: Lateral view.

Premaxilla or Incisive bones (Figures 1B, 3A, 3B, 4B and 5C\13) formed the most apical part of the upper jaw that covered by horny beak. It had three processes frontal, maxillary and palatine process. The frontal process (Figures 1B, 3A and 3A\13a) was medially fused with frontal process of nasal. Maxillary process (Figure 3A and 3B\13b) supported the lateral part of the beak and was fused caudally with the maxilla. Palatine process (Figures 2A, 4A and 5B\13c) formed ventral aspect of the beak and joined with the ossified nasal septum.

Maxilla (Figure 3A and 3B\14) formed the caudolateral sides of upper jaw and fused rostrally with the premaxillary. It had two processes; zygomatic (Figure 3B\14a) and palatine (Figures 2B, 4A and 5B\14b) processes, those attached to zygomatic and palatine bones, respectively. The two palatine processes are separated ventrally by wide palatine fissure (Figures 2A and 4A\PF).

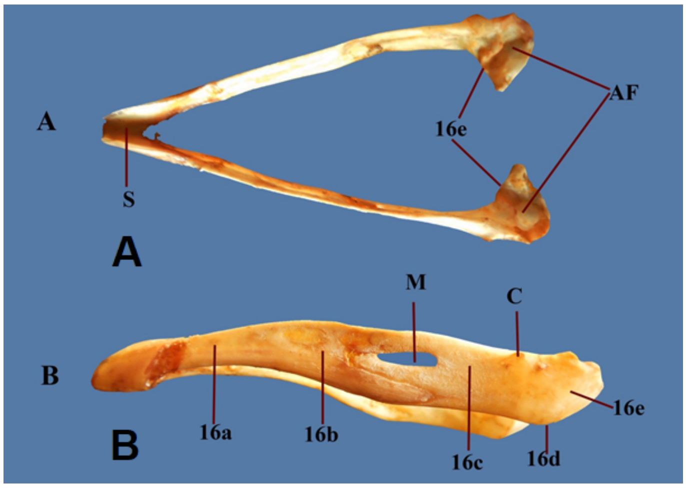

Figure 6: photograph showing the mandible. A: Dorsal view; B: Lateral view.

1-Occipital bone, 1a-Supraoocipital part, 1b-Basioocipital part, 1c- Exo-oxcipital part, 1d-Occipital condoyle, 2-Parital bone, 3-Frontal bone, 3a- longitudinal fissure, 4- Sphenoid bone, 4a-Presphenoid, 4b-Basisphenoid, 5-Squamus part of temporal bone, 5a-orbital process, 5b-Zygomatic process, 5c-temporal fossa, 6- Ear capsule, 6a- Internal acoustic meatus, 6b- Tympanic cavity proper, 7- Lacrimal bone, 7a- dorsal lacrimal process, 7b-ventral lacrimal process, 7c- deep fissure, 8-Quadrate bone, 8a- Orbital process, 8b- Otic process, 8c- Articular process, 9- Zygomatic (Jugal) bone, 9a Jugal process , 9b-Proper jugal, 9c- Quadrojugal process,10- Palatine bone, 11-Vomer bone, 12- Nasal bone, 12a-Frontal process of Nasal, 12b- Maxillary process of Nasal, 12c- Premaxillary process of Nasal, 12d- Frontonasal hing 13- Inscisive bone (premaxillary bone), 13a- Frontal process of incisive, 13b-Maxillary process of incisive , 13c- Palatine process of incisive, 14-Maxillary bone, 14a-Zygomatic process, 14b-Palatine process of maxilla, 15-Ethmoid bone, 15a –vertical part of Ethmoid, 15b- Horizontal part of Ethmoid, 16-Mandible, 16a- Dental bone, 16b-splenial bone, 16c- supra angular bone, 16d-The angular bone, 16e-The articular bone. N: Nuchal crest, FM: Foramen Magnum, OP: Optic foramen, E: Ethmoid foramen, PF: Palatine fissure, PT: Pterygoid facet, M: Mandibular foramen, C: Coronoid process, S: Mandibular Symphysis, AF: Articular facet for quadrate bone, OL: olfactory foramen.OC: Orbital Cavity, ON: Osseous opening of nostril, NS: Nasal Septum, CC: Cranial cavity.

Palatine bones (Figures 1A, 2A, 4A and 5B\10) were horizontal, thin bony plates, presents on both sides of vomer bone. It joined rostrally the palatine process of maxilla while caudally reached the presphenoid.

Vomer bone (Figure 1A, 2A, 4A and 5B\11) was an unpaired thin plate situated in the median plane between the palatine bones. It caudally fused with the presphenoid and has free pointed end rostrally.

The lacrimal bone was a large triangular bone; its base faced the rostral margin of orbit while its apex met the maxillary process of nasal bone. It consisted of dorsal (Figure 3A\7a) and ventral (Figure 3A\7b) lacrimal process in between deep fissure (Figure 3A\7c).

Zygomatic bone or Jugal bone (Figures 2A, 3A, 4A, 4B and 5B\9) is paired, elongated rod-like bone, connected to the maxilla cranially through jugal process (Figure 3B\9a) and to quadrate bone caudally through quadratojugal process (Figure 3B\9c). In between the jugal process and quadratojugal, the proper jugal bone (Figure 1A and 3B\9b) presented.

Ethmoid bone made of horizontal and vertical plate. The horizontal one (Figure 3B\15b) was located craniodorsal forming the cranial osseous part of the interorbital septum, it related dorsally to the floor of frontal bone. The vertical plate (Figure 2A and 3B\15a) was thick and placed cranioventrally, Also, it shared in the formation of interorbital septum and separated the nasal cavity rostrally from orbital cavity caudally. The craniodorsal part of interobital septum was perforated by the paired olfactory foramen, while the caudal part contained large optic foramen (Figure 3B\OP) and small ethmoid foramen (Figure 3B\E) just dorsal to the latter foramen.

The quadrate bone (Figure 2B, 4A, 4B and 5A\8) consisted of three processes; orbital, otic and articular (mandibular) process. The orbital process (Figure 2B\8a) directed rostromedially towards the orbit. The otic process (Figure 2B\8b) was inserted dorsally in the squamous part of temporal bone. The articular process (Figure 2B\8c) divided into lateral and medial condyles in between shallow notch, those condyles articulate with articular facets of mandible.

Mandible (the lower jaw) (Figure 4b/16), (Figure 5C, 6A and 6B) was V-shaped bone, comprised of several bones that were difficult to separate. It formed of two equal halves right and left rami which united rostrally at the mandibular symphysis. It was composed of five bones; dental bone, splenial bone, supra angular bone, angular bone and the articular bone. Dental bone (Figure 6B\16a) presented just after the mandibular symphysis (Figure 6B\S) and mostly formed the frontal part of the mandible followed by splenial bone (Figure 6B\16b) that its posterior end encircled roughly with the mandibular foramen (Figure 6B\M). The lateral surface caudal to the foramen is formed by the supra angular bone (Figure 6B\16c), which carried on its dorsal border the coronoid process (Figure 6B\C). The angular bone (Figure 6B\16d) was smaller and most caudal region of the mandible; ventral to the supra-angular. The articular bone (Figure 6A and 6B\16e) was triangular in shape and its dorsal surface has articular facets (Figure 5A and 6A/AF) to articulate with the quadrate of the skull.

The cranium of owl composed of neurocranium and viscerocranium that separated by large two orbital cavities. A similar observation was reported by Choudhary et al. (2020) in eagle and brown wood owl, Süzer et al. (2018) in turkeys, Moselhy et al. (2018) in ostrich, Nyari et al. (2006) in house crow, Tahon (2013) in chickens, Shaker and El-Bably (2015) in crocodile. In agreement with the description of Choudhary et al. (2020) in eagle and brown wooden owl; Moselhy et al. (2018) in ostrich, Shaker and El-Bably (2015) in crocodile; the Occipital bones established by three parts; squamous, paired exooccipital and basioccipital ones. It enclosed a rounded foramen magnum as mentioned by (Ahmed and Al-Asadi, 2020 in turkey), although it was triangular in chickens (Tahon, 2013; McLelland, 1990), vertical oval (Choudhary et al., 2020 in brown wood owl; Süzer et al., 2018 in turkey).

Similar to the observations of Choudhary et al. (2020), the Occipital condoyle was single and rounded; moreover, it was hemispherical in ostrich (Moselhy et al., 2018) and chicken (Tahon, 2013) and pear-shaped in emu (Kumar and Singh, 2014). The Occipital condoyle has dorsal median notch, which help a large scale of rotation of the head thought atlanto-occipital joint compared to that of mammals (Dyce et al., 2010). The roof of cranial cavity formed mostly by Parietal bone caudally and frontal bone rostrally, that in coordinate with Ahmed and Al-Asadi (2020) in turkey; Tahon (2013) and McLelland (1990) in chicken, while (Choudhary et al., 2020 in eagle and brown wooden owl; Moselhy et al., 2018 in ostrich) reported that, dorsum of cranium formed mainly by frontal bone.

The parietal bones couldn't be distinctly recognized from frontal bone, also Inter-parietal bone not recognized in that study; that result also mentioned by (Ahmed and Al-Asadi, 2020; Choudhary et al., 2020; Moselhy et al., 2018; Tahon, 2013; McLelland, 1990). The Frontal bone was nearly straight externally with shallow longitudinal groove in the middle till reaching the parietal bone, while in eagle and brown owl (Choudhary et al., 2020) and ostrich (Moselhy et al., 2018) both sides of frontal bone was slopped cranio-caudally and upraised centrally by frontal elevation. The orbital part of frontal bone shared in the formation formed the medial boundary of the orbit that in line with (Ahmed and Al-Asadi, 2020; Choudhary et al., 2020; Moselhy et al., 2018; Tahon, 2013).

Sphenoid bone constructed of presphenoid and basisphenoid, the first one combined rostrally with vomer bone and the second united caudally to basioccipital, that also reported by Ahmed and Al-Asadi (2020), Moselhy et al. (2018), Tahon (2013). Although in crocodile Shaker and El-Bably (2015) reported that Sphenoid bone had another third part called alisphenoid.

In accordance with (Choudhary et al., 2020; Moselhy et al., 2018; John et al., 2016) The Temporal bone represented by ear capsule and squamous part. The later part had long, flat orbital process and small zygomatic one; that agreed with (Ahmed and Al-Asadi, 2020; Choudhary et al., 2020; Moselhy et al., 2018), whereas in crow (John et al., 2016) the zygomatic process was more pointed and longer than the orbital process. In addition to Nickel et al. (2005) whom introduced that orbital process was long and stout in duck and geese while elementary in pigeons. The ear capsule was an oval cavity but was irregular circular as recorded by (Choudhary et al., 2020; Moselhy et al., 2018). It contained dorsally the external acoustic meatus and ventrally tympanic cavity proper according to (Choudhary et al., 2020; Tahon, 2013), while John et al. (2016) visible the external acoustic meatus towards ventral part of ear capsule.

In line with (Choudhary et al., 2020; Rajalakshmi et al., 2020; Moselhy et al., 2018; Tahon, 2013) Nasal bone was a flat bone mostly formed the roof of nasal cavity and part of the upper beak, it branched into frontal, maxillary process and premaxillary. The nasal bone was relatively small as mentioned by the lateral process of nasal bone formed the lower borders of the nares. According to (Choudhary et al., 2020; Rajalakshmi et al., 2020; Moselhy et al., 2018; John et al., 2016; Tahon, 2013; Nickel et al., 2005) a well-developed and highly mobile Fronto-nasal hinge formed due to articulation between frontal bone and frontal process of nasal bone. Fronto Nasal hinge considered a characteristic feature in avian skull, which forms the base of cranial kinesis. Most of birds achieve some degree of cranial kinesis and can move the upper jaw in relation to the lower jaw, that also added by John et al. (2016) and Nickel et al. (2005). The osseous openings of nostrils were ovoid in shape with biconvex borders; it termed Holorhinal" where the opening didn't extend to the level of nasofrontal hinge as recorded by Tahon (2013) in chicken but in pigeon (Nickel et al., 2005) it was "schizorhinal" where the opening extend to nasofrontal hinge.

The quadrate bone was quadrilateral in shape as discussed by (Choudhary et al., 2020; Moselhy et al., 2018; Tahon, 2013), while in horned owl (Rajalakshmi et al., 2020) it was semicircular. It had orbital, otic and articular (mandibular) process. The orbital process directed rostrally to the orbit, the otic process of inserted into the squamous part of temporal bone. The articular process divided into lateral and medial condyles in between shallow notch; however, Hassan (2012) of hooded crow reported the presence of lateral, medial and caudal condyles. The quadrate bone assisted as a connection between the skull and mandible; also it entered in the mechanism of kinesis as reported by Nickel et al. (2005) in domestic fowl.

Similar to the observations of John et al. (2016) in crow, Rajalakshmi et al. (2020) in horned owl; the lacrimal bone was large triangular in shape, situated at the rostral margin of the orbit. It was easily differentiated from the neighboring bones and formed of dorsal and ventral lacrimal process. However, in ostrich (Moselhy et al., 2018), the lacrimal bone was a small bone, that fused caudally with frontal bone and had prominent ventral lacrimal process.

The proper jugal bone is an elongated rod-like bone; connected rostrally to maxilla with jugal process and curved caudally to join quadrate bone through quadratojugal process, that description as well as Moselhy et al. (2018) in ostrich, John et al. (2016) in crow. Vomer bone was an unpaired thin plate located in between palatine bones with free pointed end rostrally as mentioned in eagle and owl (Choudhary et al., 2020), ostrich (Moselhy et al., 2018), crow (John et al., 2016); Even though it was rudimentary in pigeon and fowl (Nickel et al., 2005).

Palatine bones were horizontal, flattened fusiform bony plates; presents on both sides of vomer bone, its rostral end joined with the palatine process of maxilla as presented in horned owl (Rajalakshmi et al., 2020) Contrarily, in crow (John et al., 2016) the proximal end of palatine bone was unevenly triangular and rod shaped towards its distal end, moreover in eagle (Choudhary et al., 2020) and ostrich (Moselhy et al., 2018) the whole palatine bone was delicate quadrilateral. Nickel et al. (2005) added that, it was rod shape in pigeon and fusiform plates in duck and goose. Premaxilla formed the apical part of the upper jaw, it had three processes; frontal, maxillary and palatine process, while maxillary bone formed the lateral sides of upper jaw and contained zygomatic and palatine processes, the later result agreed with Choudhary et al. (2020) in eagle, Rajalakshmi et al. (2020) in owl, Moselhy et al. (2018) in ostrich John et al. (2016) in crow and Indu et al. (2013) in green-winged macaw. The maxilla was greatly reduced which is characteristic feature to most birds in order to facilitate cranial kinesis and prevent the entrance of water or mud into nostrils during probing for food, consequently enable breathing while Feeding. Reduction of the maxilla led to a compensatory lengthening of the premaxilla to keep the length of the rostrum as discussed by Bout and Zweers (2001).

Similar to the observation of Rajalakshmi et al. (2020) in horned owl, the ethmoid bone had horizontal and vertical plate, the horizontal plate located craniodorsaly forming the anterior osseous part of the interorbital septum and fused dorsally to ventral aspect frontal bone while in ostrich Moselhy et al. (2018) found that, horizontal plate was beneath the nasal bones and frontal process of premaxilla, more over the horizontal part was reduced and lateral masses were absent in crow (John et al., 2016). The vertical plate was thick and separated the nasal cavity rostrally from orbital cavity caudally, that in line with Rajalakshmi et al. (2020) in horned owl and Moselhy et al. (2018) in ostrich. The interobital septum was perforated caudally by large optic foramen and small ethmoid one that approved in chicken (Tahon, 2013), but the optic foramen was smaller in crow.

The mandible comprised of two equal halves that formed mainly of five bones; dental, splenial, supra angular, angular and the articular bone, while Shaker and El-Bably (2015) confirmed the presence of another six bone (coronoid) in crocodile's mandible. The mandible fused rostrally forming the mandibular symphysis and had only single mandibular foramen which agreed with John et al. (2016) in crow, contrarily in eagle and brown wood owl (Choudhary et al., 2020), ostrich (Moselhy et al., 2018), the mandible contained numerous rostral and caudal mandibular foramina. Additionally, the mandible of crocodile occupied external and internal mandibular fenestra (Shaker and El-Bably, 2015). The articular part of mandible was triangular in shape, its dorsal articular cavity enclosed medial and lateral facets to form movable joint with quadrate bone, later result also described in eagle and brown wood owl (Choudhary et al., 2020), ostrich (Moselhy et al., 2018), emu (Kumar and Singh, 2014). Furthermore, three facets; medial, lateral and caudal facets were present in the cattle egret (Hassan, 2012).

NOVELTY STATEMENT

Our work provide further anatomical information about the bony structure of owl's skull which is important to zoologists for taxonomy, moreover it aids veterinarian in understanding the interpretation of X-ray images that needed in dealing with wild bird's surgical affections mainly in cranium.

AUTHOR'S CONTRIBUTION

AMI and RS: Designed the research work, performed anatomical preparation of the skull. AMI: Made X-ray Image. RS: Achieved C.T studies. All authors revised the manuscript and approved the last version of the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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