Research Paper

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Anatomical Studies on the Skull of Crow (*Corvus splendens*)

Veterinary Science

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ABSTRACT

The present study was conducted on seven Crows (Corvus splendens) collected dead. Maceration was carried out with plane water and bones were dried under direct sunlight. The skull of crow did not show any marked difference from typical avian skull. Occipital bone contributed to the formation of foramen magnum.Supra occipital part of this bone presented a raised area which is comparable to the external occipital protuberance of mammals. Foramen magnum was the largest foramen of the skull. Parietal bone was not clearly demarcated. Post-sphenoid was well developed and triangular in outline. Pre-sphenoid bone formed ventral portion of inter orbital septum. Lacrimal bone was very well developed with a ventrally directed lacrimal process. Its shape varied from triangular to roughly quadrilateral. Pre-maxilla was a highly developed bone. Maxillary bone was highly reduced and zygomatic bone was in the form of a thin rod. Pterygoid bone was in the form of a short rod and vomer bone was in the form of single bony palate located in median plane. The nasal frontal hinge was highly mobile in the skull of crow. Quadrate bone was quadrilateral in shape and presented two processes and two condyles. Mandible was a single bone with two halves fused rostrally approximately at an angle of 30° and formed the lower beak. In conclusion, the gross morphological features of crow skull resembled to the typical avian skull with minor variations.Well-developed nasal frontal hinge,larger bill length with its wider base and hooked nature indicated the fruit eating behavior of this bird.

Summary: The present study was designed with the aim to understand the morphological features of skull of crow. Foramen magnum was the largest foramen of the skull. Lacrimal bone was very well developed with a ventrally directed lacrimal process. Its shape varied from triangular to roughly quadrilateral. As compared to the rest of the skull bones,Pre-maxilla was a highly developed bone. Maxillary bone was highly reduced and zygomatic bone was in the form of a thin rod. Quadrate bone presented two processes and two condyles. Mandible was a single bone with two halves fused rostrally approximately at an angle of 30° and formed the lower beak. In general, the gross morphological features of crow skull resembled to the typical avian skull with minor variations.Well-developed nasal frontal hinge,larger bill length with its wider base and hooked nature were main observations in this species.

INTRODUCTION

Crows are a distinct species of birds, which are found in every continent of the world except Antarctica.In the Indian peninsular region there are two sub-species of crows, namely the common House crow (*Corvus splendens protegatus*) and the larger and darker Jungle crow (*Corvus macrorhynchosculminatus*). Crows are both omnivores and scavenger and their diet consists of rodents such as mice, rats, squirrels and fruits (Nyari *et al.,* 2006). Skull of birds like that of mammals is categorized into cranial and facial bones. The cranial bones help in the formation of cranial cavity to enclose the most vital organ,the brain.The skull of birds in general is elongate in shape with characteristically large orbits tapering towards the tip of a long rostrum. The rostrum is made up of teeth less jaws covered by a horny sheath, known as the ramphotheca. Bird jaws are powerful tools used for feeding especially in the birds of prey. The temporal fenestrae and the ant-orbital fenestra in both paleognaths and neognaths have merged with the orbit (Knutsen, 2007). Modern birds, having lost their postorbital bone, no longer possess fully isolated supra- and infra-temporal fenestrae. These modifications inbirds lighten the skull and facilitate the development of an enlarged brain. One of the important features of birds is cranial kinesis which implies the ability to move the upper bill, or a part of it, relative to the brain case. Cranial kinesis is generated by a complex mechanism in the skull. Quadrates, pterygoids, palatines, jugal bars and all associated muscles and ligaments work together by a complex mechanism. Gross morphological studies on the skull of domestic fowl, pigeon and goose have been discussed in various text books of anatomy (Nickel *et al.*, 1986 and Dyce *et al.,* 2009). However, very scanty information is available on the skull of crow. Therefore, the present study was planned to investigate the gross anatomy of corvid skull.

MATERIAL AND METHOD

The present study was based upon seven crows (*Corvus splendens*) collected dead.The likely cause of death was entrapment of their wings in kite threads which were found around their wings. No special technique was used for collection of bones as the birds had dried due to prolonged hanging on trees. For cleaning the bones 10-15 % washing soda (Duzler *et al.*, 2006) was used, rinsed with tap water and bones were dried under direct sunlight. After thorough gross anatomical study, the morphometryof different bones of skull was carried out and the following different measurements were recorded: length, width and height of cranium,length, width and thickness of upper beak, length and width of lower beak, skull length, interorbital width, nasal frontal hinge width, average diameters of foramen magnum,external nares and mandibular foramen. Cranial length was recorded between two lines drawn perpendicular to nasal frontal hinge and caudal end of skull (Fig.1/b). Width of the skull was calculated between the orobasal articular grooves on either side of temporal bone. The height of cranium was calculated from the highest point of frontal bone to the point between the two basilar tubercles of basi-occipital bone (Fig.1/a). Length of upper beak was calculated from the nasal frontal hinge to the tip of upper beak (Brusaferro and Insom, 2009), whereas, width and height of upper beak was calculated at three different regions viz. proximal (just anterior to lacrimal bone), middle (at the level of anterior boundary of nares) and distal parts (at the level of palatine process). Lower beak length was measured by drawing an arbitrary parallel line (Fig.1/c) drawn from the tip of lower jaw to the center of base (Elrot and Shimitz, 2010). Width of lower beak/

bill was calculated at three different regions viz. just distal to articular bone,at the center of ramus and at the level of fusion of two rami.The average diameters of foramen magnum, mandibular foramen and external nares were taken as the average of vertical and horizontal diameters. Photographs of bones were taken using digital camera.

RESULTS

The skull of crow, like atypical avian skull, was characterized by absence of the inter-parietal bone. Unlike mammals, the middle ear ossicles were replaced by quadrate bone. Occipital bone contributed to the formation of foramen magnum (Fig.2/1&3/1). A raised area (Fig.2/2), homologous to external occipital protuberance of mammals, was present on supra occipital part (Fig. 2/7) of occipital bone. The free border of basi-occipital (Fig. 3/2) presented a single round occipital condyle (Fig. 2/5). The lateral occipital (Fig. 2/3) presented a number of small foramina for passage of different nerves. Foramen magnum, the largest foramen of the skull, was directed caudo-ventrally and located at lower position to cranium. With respect to basi-occipital, foramen magnum was located at an acute angle. Parietal bone was not clearly demarcated and hence the authors were not convinced to confirm its location. However, a thin bony plate, which was observed between supra-occipital, frontal and temporal bone, might be associated with the parietal bone. Post-sphenoid (Fig. 3/3) bone was well-developed and triangular in outline. It comprised of a body and two temporal wings. The pre-sphenoid (Fig.3/4) bone was distinguished into body and orbital wings. The body of the pre-sphenoid on either side articulated with rostral ends of pterygoid bones. Pre-sphenoid partly contributed to formation of interorbital septum. Ethmoid bone (Fig. 4/14) was in the form of a vertical plate and formed the major portion of interorbital septum (Fig.4/13). Horizontal part was reduced and lateral masses were absent. The interorbital septum was pierced by inter-orbital septal notch (Fig. 4/5). Optic (Fig. 4/4) foramen was located adjacent to caudal boundary of this notch. Frontal was the largest bone of cranium in crow and formed the roof of cranial cavity. It comprised of three parts frontal, orbitaland nasal. The frontal part (Fig. 5/6) of frontal bone, located just above the orbits on either side, was merged with the parietal region. Orbital part (Fig. 5/7) formed the major portion of the surface of orbit. The nasal part (Fig. 5/5), which was located between two orbits, terminated at fronto-nasal hinge.

Temporal bone was represented by two parts viz. ear capsule (Fig. 4/1) and squamous part (Fig. 4/16). External acoustic meatus (Fig. 4/2), visible towards the ventral part of ear capsule, led to the floor of this meatus. An articular cavity (orobasal articular groove), present in ear capsule, was in articulation (Fig. 4/3) with otic processs of quadrate bone. Squamous part unveiled two processes, orbital (Fig. 5/8) and Zygomatic/suprameatal process (Fig. 5/9 & Fig. 4/15). Lacrimal bone (Fig. 4/12) formed a movable joint with nasal bone. The lacrimal, with a well-developed and ventrally directed lacrimal process (Fig. 5/12), was easily differentiable from the adjoining bones. The shape of this bone varied from triangular to roughly quadrilateral. Frontal process (Fig. 5/3) of nasal bone was fused with the nasal part of frontal bone. Intermaxillary process (Fig. 5/2) of nasal bone formed the dorsal border of nares and its lateral process (Fig. 5/10) formed the aboral and lower borders of nares. The orbit and nasal cavity were connected with each other through the fenestrae present at the dorsal and ventral aspects of the lacrimal bone. A well-developed and highly mobile nasal frontal/ cranio facial hinge (Fig. 5/4) was formed due to the articulation between frontal processof nasal bone with the rostral border of frontal bone. Pre-maxilla was very well developed and presented three processes viz. maxillary, palatine and nasal. The Maxillary process (Fig. 5/11), which was fused with maxilla, formed the lower border of nares. Palatine process helped in the formation of bony plate. Nasal process (Fig. 5/1) joined to the inter-maxillary process of nasal bone to form the major portion of upper beak. The ratio between skull length and upper bill length was 1.7. Maxillary bone (Fig. 4/11) was highly reduced and formed the caudal boundary of external nares. Zygomatic bone (Fig. 4/7) was in the form of a thin rod like structure. The caudal end of this bone formed a movable joint with a depression on quadrate bone. Orbital cavities (Fig. 4/17), located on either side of frontal bone, were separated by inter-orbital septum (Fig. 4/13). An orbital fossa (Fig. 4/8) was triangular in shape. External nares (Fig. 4/9) was elongated in shape and its boundries were contributed by nasal, intermaxillary and maxillary bones. Palatine bone was roughly triangular (Fig. 3/6) at its proximal end and rod (Fig. 3/7) shaped towards distal end. Pterygoid (Fig. 3/8),which was in the form of short rod shaped bone, articulated rostrally with the palatine as well as pre-sphenoid and caudally with the quadrate bone. Vomer (Fig. 3/5) appeared as a single bony palate located in median plane. Quadrate bone (Figs. 2/4 & 3/9) was quadrilateral in shape and presented two processes and two condyles. Orbital process (Fig. 6/1) was elongated plate like and directed towards orbit. The otic process (Fig. 6/2) articulated formed a movable joint with squamous temporal bone. Lateral condyle (Fig. 6/3), which carried a deep articular fossa (Fig. 6/4) for articulation with quadrate-jugal bone, was elongated and well built. Medial condyle (Fig. 6/6) was very small and attached with the caudal end of pterygoid bone. The two were separated by sulcus intercondylaris (Fig. 6/5). A small tubercle (Fig. 6/7) was positioned between medial condyle and orbital process. Medial condyle presented a small articulation for the pterygoid bone and partly articulated with mandible. At the base and towards its medial aspect, the otic process displayed a pneumatic foramen (Fig. 6/8). The orbital and otic processes were placed at an obtuse angle with respect to each other. The two halves of mandible fused rostrally approximately at an angle of 30° and formed the lower beak. Each half of mandible was broadly composed of a caudal triangular part (Fig. 7/1) and a horizontal ramus (Fig. 7/2) which formed the body of this bone. The triangular part contained a deep articular cavity for articulation with temporal bone to form quadrato mandibular joint .The triangular part also displayed a sharp internal process (Fig. 7/3) and a heavily built posterior process (Fig. 7/4). At the base and towards the caudal border, the internal process presented a well-developed pneumatic foramen (Fig. 7/5). An elliptical shaped mandibular foramen (Fig. 7/6) was located at the posterior part of the ramus. The lower beak/bill (Table 1) length and width was always greater than that of upper beak.

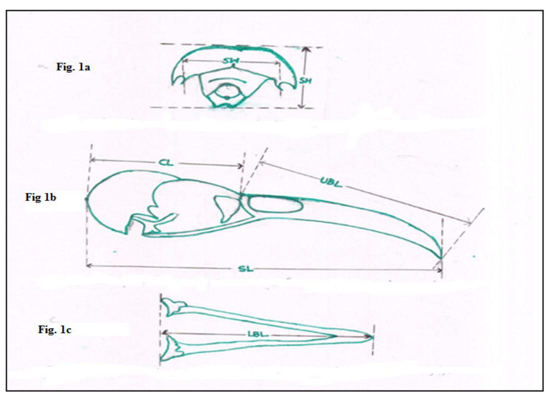
DISCUSSION

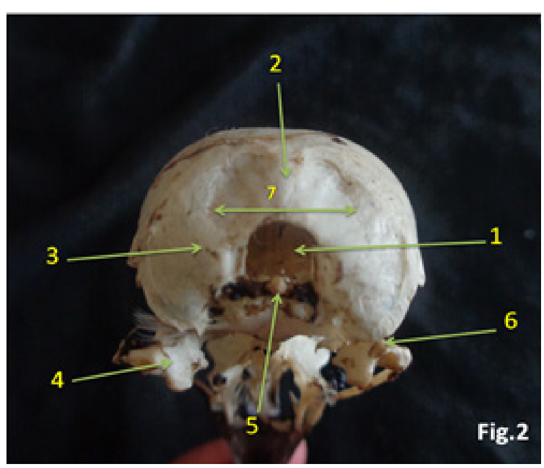
The bones of skull are not differentiable at the adult stage because of the fusion of bones with advancement of age. Foramen magnum, the largest foramen in the skull, is formed by the occipital bone. Euthenesia is performed at the atlanto-occipital joint through this foramen.The presence of single occipital condyle helps in the rotation of head on vertebral column to larger extent compared to that of mammals (Dyce *et al.*, 2009). Lobon and Buscalioni (2006) while studying avian skull morphology hypothesized a possible correlation between the positions of foramen magnum with the head posture. Birds with upward positioned foramen magnum might be characterized by more horizontal head posture and vice-versa (Kulemeyer *et al.*, 2009). Winkler *et al.* (2004) proposed that the horizontal head posture in avians might be associated with a reduced drag in flight. The *Corvus* species which are probably having a horizontal head posture might show increased flight ability, compared to Eurasian jay and black-billed magpie (Haffer and Bauer, 1993). In the present study, parietal bone was not found with distinct demarcation which may be due to the fusion between the frontal and the parietal as the parieto-frontal (Evans and Noden, 2006).Interparietal bone in birds is reported to be absent as observed in the current study. The processus zygomaticus and supra-meaticus are important insertion points of muscles and the aponeurosis of the *M.* adductor mandibular system. Brusaferro and Insom (2009) reported the presence of well-developed lacrimal bone in case of Kingfisher which formed syndesmotic joint with the frontal and nasal. Because of the lack of jugal and postorbital contact, the jugal is free to rotate forward and elevate the skull in modern birds (Nickle *et al.*, 1986 and Bock, 2000). Nasal frontal hinge, a characteristic feature of avian skull, forms the basis of cranial kinesis. All modern birds perform some form of cranial kinesis and can move the upper jaw with respect to the lower jaw to some degree. Gussekloo *et al.* (2001) during their study on three dimensional kinematics of crow (*Corvus corone*) reported the type of cranial kinesis as prokinesis and the elevation of the upper bill of the crow was 6.5°. In prokinesis the upper bill rotates around the nasal–frontal hinge and the bill itself remains inflexible (Zusi, 1984). Indu *et al.* (2013) in a study on Green Winged Macaw reported thatfronto-nasal synovial hinge joint was highly mobile and supported the well-developed prokinesis seen in this bird. The maxilla in birds is greatly reduced (Zusi, 1993), a feature which may be attributed to two different reasons. The first is that this may facilitate cranial kinesis which is observed in most birds (Zusi, 1984 and Bout and Zweers, 2001). The reduced maxilla helps in more proximal placement of the ant-orbital fenestra which provides greater vertical thrust on the rostrum. The reverse would give a more horizontal thrust and hinder a sufficient lift of the beak (Zusi, 1984). A second explanation for reduced maxilla in birds is that a proximal placement of the external nares is preferable to prevent the entry of mud or water into nostrils while probing for food in mud or water and thus enabling breathing while feeding. Reduction of the maxilla in both cases would consequently lead to a compensatory lengthening of the premaxilla to maintain the length of the rostrum. Based upon the topographic anatomy, authors have used the terms lateral process instead of maxillary process of nasal bone and nasal process for frontal process of premaxilla, previously used by Nickel *et al.* (1986). The objective of these changes was to avoid the repetition of these terminologies in the premaxilla and nasal bone. The relative contribution of the maxilla, nasal and lacrimal to the ant-orbital fossa is unclear for most taxa. However, in the current study the nasal bone did not participate in the formation of ant-orbital fossa. Fenestration present inthe nasal and lacrimal region is suggested to be pneumatic as evidenced by the extensive pneumaticity that characterizes the nasolacrimal region of birds and non-avian theropods (Witmer, 1997).

Hassan (2012) in hooded crow reported the presence of lateral, medial and caudal condyles in the quadrate bone. However, in the present study only lateral and medial condyle wereconfirmed as suggested by Bock (1964) in Corvid species. Quadrate bone acts as a bridge between skull and mandible and forms the basis for cranial kinesis. The quadrate in crow rotates approximately 10° forwards, resulting in an upward and slightly backward movement of the processus orbitalis (Gussekloo *et al.*, 2001). Mandible presents a roughly triangular part directed rostrally. This triangular area has been designated as two separate bones as articular and angular bone by Nickel *et al.* (1986). Proportionate increase in the length of the bill to that of the cranium is an adaptative feature to the insectivorous birds. Bhattacharyya (1994) reported that bill-length was considerably shorter than that of the cranium in both *Columba* and *Streptopelia,* which becomes more advantageous for ground-pecking of grains and seeds, whereas in the nearly-arboreal and fruit-eating *Treron* and *Ducula,* the wide bill-base, well-built bill and hooked tip of the upper beak are helpful adaptations of these birds in plucking and grasping large-sized fruits. In the present study the bill length (Table 1) was found to be greater than cranial length (Table1), the bill base waswider (Table 1) and the tip of the upper bill was hooked. From our study it was concluded that most of the gross features resembled to the typical avian skull with minor variations. Parietal bone was indistinct with less marked boundries. Nasal frontal hinge was very well developed and highly mobile. Quadrate bone displayed a lateral and medial condyle. Increased bill length, wider bill base and hooked beak suggest the fruit eating and seed cracking habit of Corvids.

Table 1. Morphometry of skull of Crow (*Corvus splendens*)

Parameter	Value (mean± SE) (Cm)
Cranial length (CL)	3.9 ± 0.034
Cranial width (CW)	1.63 ± 0.06
Cranial height (CH)	2.31 ± 0.05
Skull length (SL)	9.2 ± 0.14
Upper beak length (UBL)	5.3 ± 0.09
Upper beak width (UBW)	a. 1.9±0.08 b.1.27±0.04 c. 0.86±0.03
Upper beak height (UBH)	a 0.866 ±0.03 b 1.05±0.03 c 0.75±0.02
Lower beak length (LBL)	6.55 ±*0.10*
Lower beak width (LBW)	a.1.88±0.08 b.1.34±0.03 c.0.814±0.04
Interorbital width (IOW)	1.48 ± 0.04
Diameter of foramen magnum (DFM)	0.575 ± 0.02
Diameter of external nares (DEN)	1.075 ±0.04
Diameter of mandibular foramen(DMF)	0.045 ± 0.03
Nasal frontal hinge width (NF_hW)	1.6 ± 0.02





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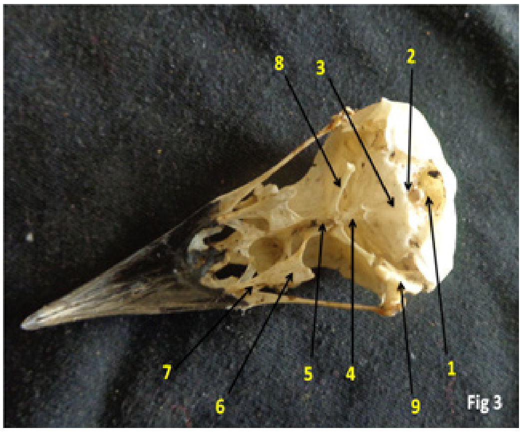

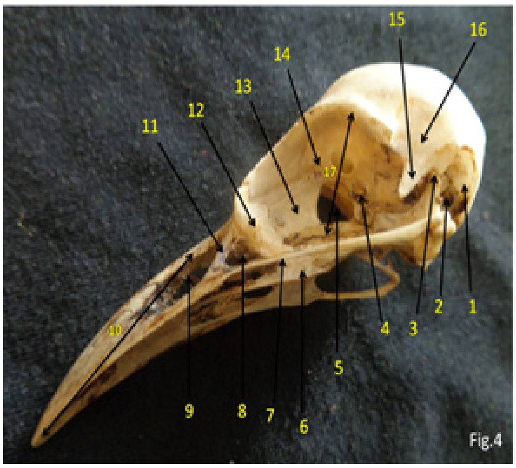

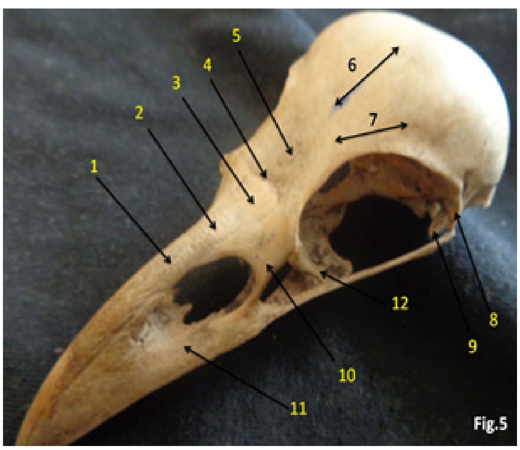

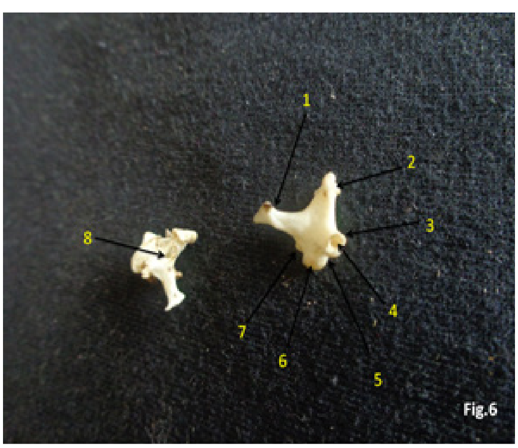

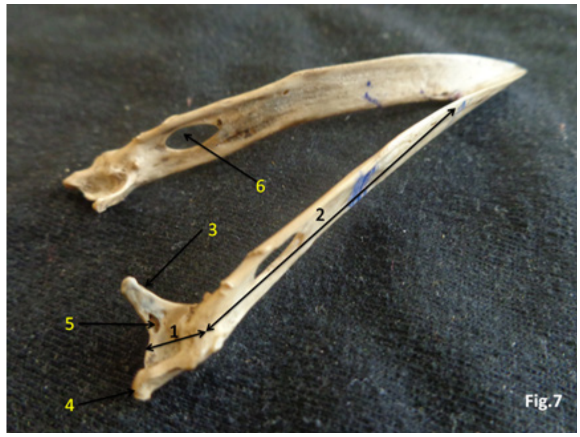

Legends

Fig.1a: Morphometry of crow skull (*Corvus splendens*), posterior view

Fig.1b: Morphometry of crow skull (*Corvus splendens*), lateral view

Fig.1c: Morphometry of lower jaw of crow (*Corvus splendens*), dorsal view

Fig.2:1.Foramen magnum 2.Raised area 3.Lateral occipital 4.Quadrate bone 5. Occipital condyle 6.Quadrato-temporal joint 7.Supra occipital part

Fig.3: 1.Foramen magnum 2.Baci-occipital 3.Postsphenoid 4.Presphenoid 5. Vomer 6. Palatine 7. Distal end of palatine process 8. Pterygoid 9. Quadrate 5. Orbital cavity 6.Lacrimal bone 7.Maxilla 8.Premaxilla

Fig.4: 1.Earcapsule 2.External acoustic meatus 3.Quadratotemporal articulation 4.Optic foramen 5.Interorbitalseptal notch 6. Palatine bone 7. Zygomatic bone 8. Ant orbital fenestrae 9.External nares 10. Premaxilla 11. Maxilla 12. Lacrimal bone 13. Inter-orbital

Septum 14. Ethmoid bone 15. Zygomatic/suprameatic process 16. Squamous part 17.Orbital cavity

Fig.5 1.Nasal process 2.Intermaxillary process 3.Frontal process 4.Nasal frontal hinge 5. Nasal part 6.Frontal part 7.Orbital part 8.Orbital Process9.Zygomatic process 10. Lateral process11.Maxillary process 12. Lacrimal process

Fig.6:1.Orbital process2.Oticprocess 3.Lateral condyle 4.Articular fossa. 5.Sulcus intercondylaris 6. Medial condyle 7. Tubercle 8. Pneumatic foramen

Fig.7:1. Triangular part 2. Horizantal ramus 3. Internal process 4. Posterior process 5. Pneumatic foramen 6. Mandibular foramen

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