

Investigation of the axial skeleton of Bengal monitor lizard (*Varanus bengalensis*): A macroanatomical study

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Abstract

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The present study was conducted to elucidate the osteological outline of the axial skeleton of Bengal monitor lizard (*Varanus bengalensis*). For that purpose, The skeletons of Bengal monitor lizard were washed, sun-dried, and used for the gross morphological study. The various osteological features of the bones of axial skeleton were observed, studied, and recorded. The study revealed that parietal bone is extensive and mainly takes part in the construction of the roof of the cranial cavity. The orbital rim is completely developed. The two halves of the mandible are fused incompletely by mandibular symphysis with deep masseteric fossa. The teeth are long, narrow, sharp with pointed tips, and well-developed similar to canine teeth. The vertebral column is composed of seventeen presacral, one sacral, and eight post-sacral vertebrae. The rib cage is composed of eight pairs of rounded ribs and sternum. This study provides baseline data for further archaeological and clinical cases.

1. Introduction

The monitor lizard is a reptile under the order of Squamata, belonging to the family Varanidae with about 80 recognized species [1]. *Varanus* spp are aboriginal to Africa, Asia, and Oceania. They have massive bodies, long tails, strong stout legs, forked long tongues, with elongated heads and necks. The average body length is about 20 cm; however, other species may be more in length [2] such as Komodo dragon (*V. komodoensis*) of Indonesia (3 m), *V. salvator* of Southeast Asia (2.7 m), *V. giganteus* of central Australia (2.4 m), *V. bitatawa* of Philippines (2 m). In fact, partial fossils of an extinct Australian monitor (*Megalania prisca*) of the Pleistocene Epoch showed that this lizard have had a body weight of 600 kg and 7 meters in length [3][4]. As for the Bengal monitor (*Varanus bengalensis*), the snout-to-vent length (SVL) can reach up to 175 cm with a tail of 100 cm and a body weight of around 7.2 kg. Usually, monitor males are larger than females. Most of the *Varanus* species are terrestrial and carnivorous, but few are arboreal and semiaquatic [5][6].

Bengal monitor lizards enforce a vital function in agricultural and forest ecological systems by feasting on insects, rodents, bird eggs, snakes, fish, and crabs, thereby maintaining the natural equilibrium in their environment. However, the population of this lizard is dwindling due to its organs being used in traditional medicine and magic [7][8]. Its venom is also used in science and research as an anticoagulant [9][10]. Furthermore, the small lizards and eggs are consumed as a delicacy [11]. Therefore, it is essential to conserve this specie to prevent extinction and maintain the balance of agricultural and forest ecosystems.



Having a detailed understanding of the axial skeleton structure of animals is of extreme importance in species identification and conservation. This knowledge assists frameworks in Zoos, Laboratories, wild animal medicine, archaeology, and anthropology. To our knowledge, no systematic study has been conducted on the macroanatomical structure of Bengal monitor axial skeleton and osteological information in this regard are scarce. Therefore, the focus of this study is to construe the osteological outline of the axial skeleton bones of Bengal monitor lizard.

2. Material and Methods

2.1. Study material

The skeletons of three monitor lizards were used in the current study. The permission for the specimen collection has been obtained from the divisional forest officer, Divisional Forest Office, Ministry of Environment, Forest and Climate Change, Government of the Peoples Republic of Bangladesh. The present work was carried out from July 2021 to June 2022.

The carcasses of three mature Bengal monitor lizards were collected from Reptiles farms limited, Uthura, Bhaluka, Mymensingh, after natural death. The carcasses were buried for three months with precaution and protection to avoid small bones missing in the premises of Sylhet Agricultural University, Bangladesh. After extraction, the bones were washed with bleaching powder to get rid of the offensive odor, then, they were dusted and sun-dried for one week. The bones were then collected, sorted, and stored in separate boxes.

2.2. Macro anatomical investigation

The study was carried out at the Anatomy Laboratory, Department of Anatomy and Histology. Various osteological features of the axial skeleton bones were observed, studied, measured, and photographed with a DSLR camera (Nikon D5500, Japan).

3. Results

The axial skeleton is constituted of the skull, mandible, vertebral column (presacral, sacral, and post-sacral vertebrae), in addition to ribs with their derivatives and the sternum.

3.1. Skull

The skull is oval and elongated. The interparietal fuses with the occipital before birth. Parietal bone is extensive and mainly takes part in the formation of the cranial cavity roof. Frontal and Nasal bones are paired, narrow, and fused with a well-developed sutural joint (Fig. 1 A). Maxilla is well-developed and has sockets for incisors, canine, premolar, and molar teeth (Fig. 1 A). The teeth are well-developed, long, narrow, and sharp with pointed tips. The lateral parts of the occipital condyle, which form the walls of the subcircular foramen magnum, are called otooccipital. The basioccipital forms the floor of the foramen magnum, the ventral surface of the posterior endocranial cavity, and major parts of the subcrescentic occipital condyle. The orbital rim is incomplete in both dog and monitor lizard but separated by an opening in lizard compared to the dog where it is separated by a cavity. The zygomatic process is highly curved (Fig. 1 A).

3.2. Mandible

The two halves of the mandible are fused incompletely by mandibular symphysis (Fig. 1 B) [12]. Each half possesses three parts (articular, dentary, and coronoid). The dentary part bears two alveoli for the incisor, one for the canine, and three for the premolar and molar tooth. Laterally the ramus of the mandible presents a deep and well-developed depression known as the masseteric fossa (Fig. 1 B).

3.3. Vertebral column (backbone)

Vertebral column is constituted of presacral, sacral and post-sacral vertebrae. The presacral vertebrae is comprised of the cervical and trunk (combination of thoracic and lumbar vertebrae) with a total of 17 vertebrae. The post-sacral vertebrae designate only caudal /coccygeal vertebrae, and in total, eight were found in Bengal Monitor.

3.3.1. Presacral vertebrae

3.3.1.1. Cervical vertebrae

Nine cervical vertebrae are present in the investigated monitor lizards. Cervical vertebrae are well developed with strong bodies in comparison to other vertebrae.

First (Atlas) Cervical vertebra

The spinous process is in the form of mid-dorsal crest but the caudal part forms a thick tubercle and its midpoint bears a notch to accommodate the apex of the spinous process of the second vertebra (axis). The spinous process is divided into two small tubercles directed caudally. The posterior process is short and narrow. The first intercentrum is keeled (Fig. 1 C).

Second (C₂-Axis) and third (C₃) cervical vertebra

The postzygapophysis of the axis has a posterior process and the transverse process projects caudally. The second intercentrum has one pair of crests (Fig. 1 C), while the third intercentrum is fused to the C₂ centrum (Fig. 1 D). The transverse process is long, narrow, spinous, and directed caudally. The spinous processes are inclined somewhat cranially.

Fourth (C₄) to ninth (C₉) cervical vertebra

There are nine cervical vertebrae. All the neural spines are in the form of a medial crest and tuberos projected parts are directed caudally. The cervical neural arches are longer than the trunk neural arches. The neural arch has additional articulating processes as pre- and post-zygapophyseal (Fig. 1 E).

3.3.1.2. Trunk (thoracic and lumbar) vertebrae

A trunk is formed normally by the union of thoracic vertebrae and lumbar vertebrae. In the monitor lizard, no lumbar vertebrae are present and the eight thoracic vertebrae form the trunk while. The bodies of vertebrae are wider, broader, and well-developed. The spinous processes are very long and somewhat inclined caudally. The dorsal part of the spinous process is thick and broader craniocaudally and the dorsal or proximal part is narrower and pointed. The transverse process of the first vertebra is narrower and clearly divided into two parts; directed laterally and caudally. The transverse process of the remaining vertebrae is rudimentary and forms a thick tubercle (Fig. 1 F).

3.3.2. Sacrum

The Sacrum of monitor lizard is roughly triangular in outline and is formed by the fusion of three sacral vertebrae. It has two surfaces, two borders, a base, and an apex (Fig. 1 G). The median sacral crest possesses three separate spinous processes. The lateral sacral crest is less developed and bears a single spine. Two pairs of lateral vertebral foramina are present. Monitor lizards have a first sacral vertebra with wide or broader lateral processes (sometimes called sacral ribs) that articulate with medium ilium like other lizards (Fig. 1 G).

3.3.3. Caudal/ coccygeal vertebrae

Eight caudal vertebrae are present in monitor lizards and these vertebrae decrease in size gradually. However, every caudal vertebra bears a well-developed transverse process inclined or bent caudally. The first two or three caudal vertebrae possess vertebral foramina, while the others do not have any vertebral foramina (Fig. 1 H).

3.4. The ribs

The study revealed the presence of eight pairs of ribs. The first few pairs are smaller like other animals, the proximal part is curved and bears a head, neck, and tubercle. The distal ends are somewhat flat dorsoventrally. The body or shaft of the first few ribs is dorsoventrally flattened, while the rest are almost rounded (Fig. 1 I).

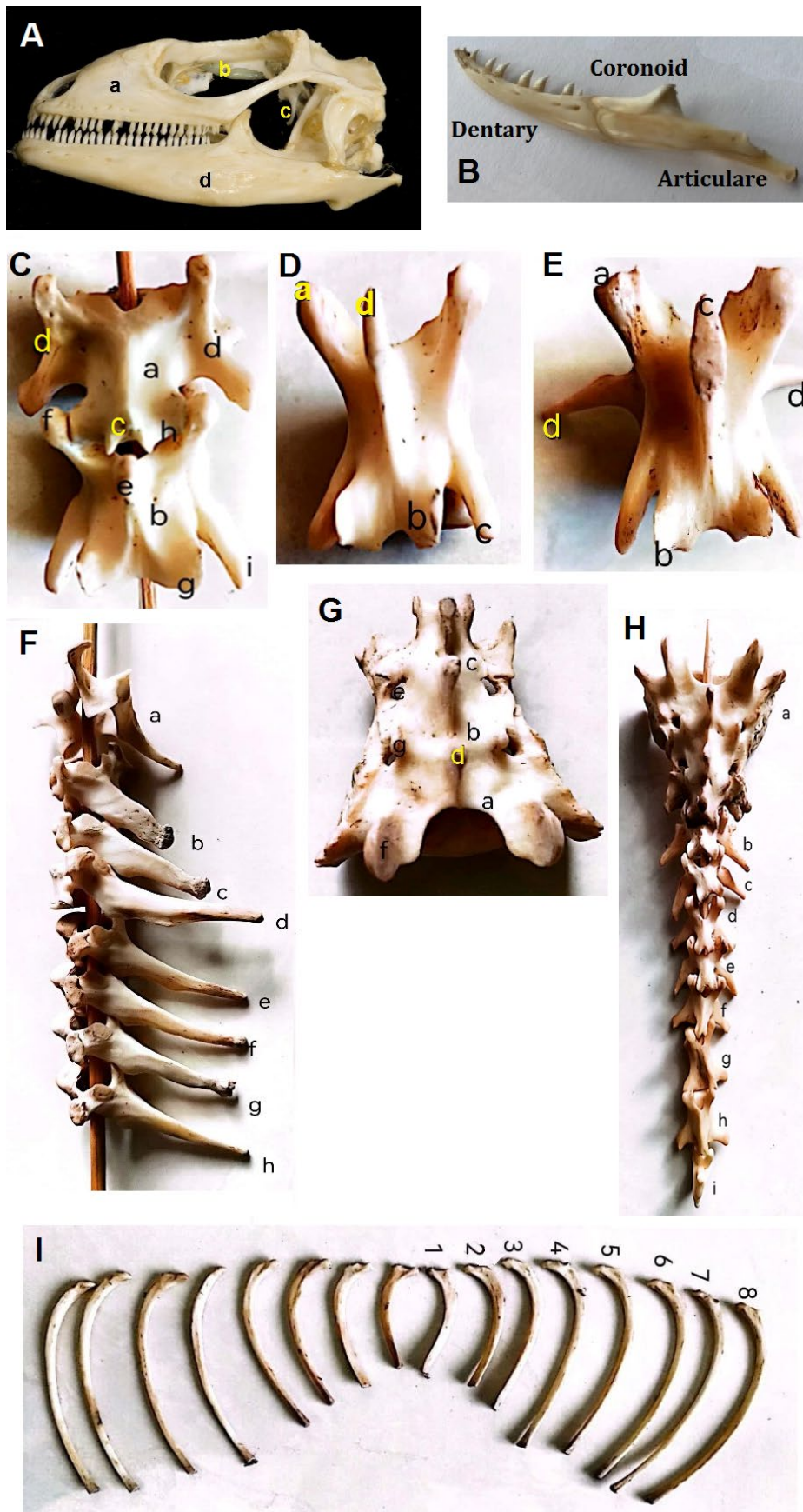


Figure 1. The macro structure of Bengal monitor lizard (*Varanus bengalensis*) axial skeleton. (A) The skull where (a) Maxilla, (b) Orbit, (c) Temporal cavity, (d) Mandible. (B) The mandible (lateral view), showing three parts (articular, coronoid, and dentary) [12]. (C) 1st and 2nd cervical vertebrae, where (a) 1st cervical vertebra, (b) 2nd cervical vertebra, (c) spinous process (thicker, bend caudally, and bifurcated), (d) transverse process of 1st cervical vertebra, (e) spinous process of 2nd cervical vertebra (sharp and tapered end run vertically), (f) cranial articular process of 2nd cervical vertebra, (g) caudal articular process of 2nd cervical vertebra. (D) 3rd cervical vertebra, where (a) cranial articular process of 3rd cervical vertebra, (b) caudal articular process, (c) transverse process, (d) spinous process (sharp and bend cranially). (E) 4th cervical vertebra, (a) cranial articular process, (b) caudal articular process, (c) spinous process, (d) transverse process. (F) The trunk vertebrae (thoracolumbar vertebrae), where; (a-h) represent the eight thoracolumbar vertebrae. (G) The sacrum, where (a) 1st sacral vertebra, (b) 2nd sacral vertebra, (c) 3rd sacral vertebra, (d) spinous process, (e) lateral sacral foramen, (f) cranial articular process of sacrum, (g) lateral sacral crest of sacrum. (H) The sacrococcygeal part of vertebral column, where (a) sacrum, (b-i) represent the 1st to 8th coccygeal /caudal vertebrae. (I) The ribs.

4. Discussion

The anatomical features of the monitor lizard skull were found to resemble higher vertebrates such as small mammals (dog) [13][14]. The tuatara (*Rhynchocephalia*) and crocodile skull bear two temporal openings diapsid whereas snakes and lizards (such as the monitor lizard) have modified diapsids with only one dorsal opening [15]. This modification has empowered the quadrate bone to move anteriorly and posteriorly without any rigid association, which established streptostyly and provides snakes and lizards with a kinetic skull [16]. In fact, the skull of the monitor lizard is more rigid compared to that of snakes with fewer mobile jaws.

There are four rows of teeth in each jaw. Similar to other lizards (except for Agamidae and Chamaeleonidae), the teeth are peg-like and constantly supplanted. However, monitor lizard does not have any fang teeth unlike beaded lizard (*Heloderma horribilis*) and the Gila monster (*Heloderma suspectum*). The skull articulates with the atlantal cervical vertebra via a single occipital condyle [17].

The anatomical features of mandibles were found to resemble those in dogs [13][14]. Two strong and well-developed mandibles are present in the Bengal monitor lizard which are fused strongly with mandibular symphysis. Therefore, the movement of jawbones is limited, unlike snakes that lack a mandibular symphysis so the jawbones can move apart and literally 'walk' along the prey [6].

In total, 28 vertebrae (presacral, sacral and post sacral) were found in Bengal monitor in this study. The number of vertebrae differs between species, with 27–35 presacral and 47–137 postsacral vertebrae [6], while 55 presacral vertebrae, two sacral, and 95–97 caudal vertebrae were found in Anguines lizard (*Pseudopus apodus*) [2].

The 18 presacral vertebrae in Bengal monitor lizard represent one of the smallest number of presacral vertebrae known in reptiles [18]. Among these, Monitor lizard have nine cervical vertebrae which aid support [19][20] and are similar to those found in other reptiles such as crocodiles, chelonia, and turtles [7]. However, snakes may bear between two (only atlas and axis), and 400 cervical vertebrae based on their size [21]. Atlas and axis in Bengal monitor lizards are well developed similar to their descendants higher mammals (dogs) which is in accordance with [18] who stated that the first two or three cervical vertebrae are remarkably distinguished in all reptiles as in the higher animals.

The study revealed that the trunk in monitor lizards is formed of eight trunk (thoracic) vertebrae without lumbar vertebrae. It is also probable that there were no distinguishable differences between thoracic and lumbar vertebrae. This observation is similar to previous reports [22] that the presacral vertebrae of reptiles are not differentiated into thoracic and lumbar groups. The number of trunk vertebrae (dorsal vertebrae) differs in other species. For instance, ten dorsal vertebrae were reported in Chelonian reptiles whereas eleven in Chameleons and about twelve in the pterodactyls [18].

Monitor lizards have three sacral vertebrae with wide or broader lateral processes, which is in accordance with the findings of [23] who found most reptiles possess two to three sacral vertebrae. The current observations are also supported by the study of [18] who stated that land reptiles usually have one to four or five fused or separate sacral vertebrae, In another study, [2] it was noticed that anguine lizard possesses a fused sacrum comprised of two bones. Eight caudal vertebrae were observed in the Bengal monitor lizard. This number of caudal vertebrae is considered high among reptile species since it was reported to range between one and six vertebrae [18].

The trunk (thoracic vertebrae and lumbar) vertebrae have eight pairs of ribs generally on either side, which is normal among lizards [24]. The sternum is still cartilaginous and attached to the ribs. Although the general characteristics of ribs were mentioned in the current study, the sternum and costal cartilage were not described since the burying method was used to obtain bones. Therefore, no comments are made regarding the sternum/sternal, asternal, and floating ribs present in Bengal monitor.

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