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Gross and morphometric studies on scapula of Indian elephant

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Elephant belongs to the order Proboscidea and is a non-ruminant herbivore, of the family Elephantidae with two living genera and species of elephants, *Elephas maximus* of Southern Asia and *Loxodonta africana* of Africa. The Asian elephants are subdivided into four different subspecies: *Elephas maximus maximus*, *Elephas maximus indicus* of Asia, *Elephas maximus sumatranus* and *Elephas maximus borneensis.*

The fore and hind limbs of elephants are arranged in an almost vertical position under the body, similar to a pillar or leg of a table rather than being in the angular position seen in many other quadruped mammals to support great weight. Elephant can remain standing for long periods with the support of bones and limbs. The shoulder, elbow and knee joints of elephant are stacked one above the other to hold up its heavy bulk similar to an architectural column; the downward scapula is in line with the stout humerus and ulna.

The aim of this study was to elucidate the osteological outline on the scapula in Elephants, thereby making more contribution in filling the gap of knowledge and skills framework in this field. This study provides a baseline data for further vetero-legal, archaeological and clinical cases.

For the present study, material from three Indian elephants of either sex were used. The permission for the specimen collection has been obtained from the Principal Chief conservator of forest and wildlife warden, Government of Madhya Pradesh, vide letter no 239/6998261 dated 29.12.2020.

The skeletons which were buried from last 5-10 years (2005-2010) in the premises of College of Veterinary Science and Animal Husbandry, Mhow were dug out from the grounds. Subsequently, the specimens were sort out and cleaned in running tap water.

The gross study was carried out in Osteology laboratory, Department of Veterinary Anatomy, College of Veterinary Science and Animal Husbandry, Mhow. Various osteological features of scapula in right and left fore limbs were recorded. The weight of scapula was taken by weighing machine and the length, width and circumference of scapula was taken with the help of inelastic thread and measuring tape and routine statistical analysis was done as per Snedecor and Cochran (1994).

The scapula is a well-developed flat bone of fore limb as reported by Smuts and Bezuidenhout (1993) in African elephant, Mahapatra *et al.* (2016) in adult rhino and calves and Onwuama *et al*. (2021) in West African giraffe. In the present study, it was irregularly triangular in shape as also elucidated by Smuts and Bezuidenhout (1993) in African elephant; Gupta *et al*. (2017), Gupta and Deshmukh (2014), Lambate *et al*. (2009) in camel; Damian *et al*. (2012) in giraffe; Nurhidayat *et al.* (2015) in Sumatran rhino and Mahapatra *et al.* (2016) in adult rhino and calves. It had two surfaces (lateral and medial), three borders (cranial, caudal and dorsal) and three angles (cranial, caudal and glenoid) as mentioned by Smuts and Bezuidenhout (1993) in African elephant and Lambate *et al*. (2009) in camel and Onwuama *et al*. (2021) in West African giraffe. The lateral surface was divided into two unequal fossa by a prominent scapular spine (Fig. 1) as mentioned by Smuts and Bezuidenhout (1993) in African elephant and Ahasan *et al*. (2016) in Asian elephant. The cranial supraspinous fossa was smaller while the caudal infraspinous fossa was longer as mentioned by Smuts and Bezuidenhout (1993) in African elephant, and Mariappa (1986) in Indian elephant. The supraspinous fossa was cranial to scapular spine; was smooth, elongated and slightly concave. Sarma *et al.* (2007) investigated that the supra-spinous fossa was roughly quadrilateral in sambar deer. The large concave infraspinous fossa accompanied most of the lateral surface of the triangle as described by Ahasan *et al.* (2016) in Asian elephant and was triangular in shape as noted by Smuts and Bezuidenhout (1993) in African elephant. The infraspinous fossa occupied 4/5th part of the lateral surface of the bone as noted in Indian elephant calf by Mariappa (1986). The upper and lower part of infraspinous fossa was smooth, while the middle part was rough.

The height of the scapular spine was lowest in proximal part, but it increased towards the distal part, and was

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Fig. 1. Lateral view of right scapula showing lateral surface (A), scapular spine (B), supraspinous fossa (C), infraspinous fossa (D), glenoid cavity (E), supraglenoid tubercle (F), hammate process (G), acromion process (H), cranial border (I), caudal border (J), dorsal border (K), cranial angle with small tuberosity (L), caudal angle with triangular tuberosity (M) and rough tuberosity on spine (N).

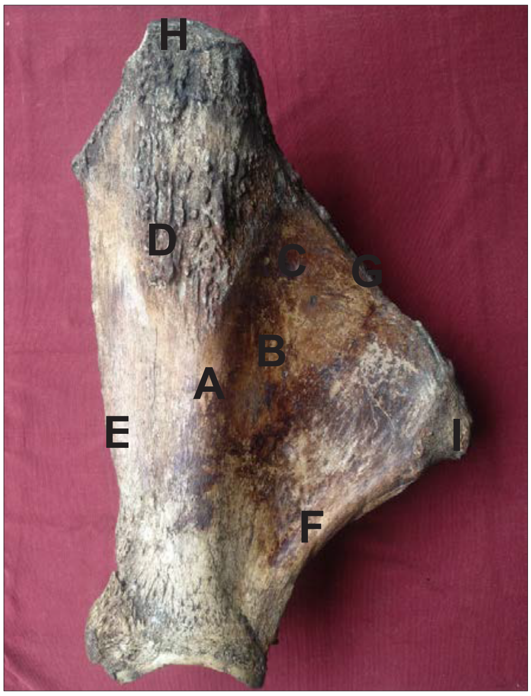

Fig. 2. Medial view of left scapula showing medial surface (A), subscapular fossa (B), caudal large triangular fossa (C), cranial facies serrata (D), cranial border (E), caudal border (F), dorsal border (G), cranial angle with small tuberosity (H) and caudal angle with triangular tuberosity (I).

maximum near the acromion process in agreement with Smuts and Bezuidenhout (1993) in African elephant. Mahapatra *et al.* (2016) examined the scapula of adult rhino and calves and revealed that the scapular spine was triangular in shape and with well-developed tuberosity but the acromion process was absent in both calf and adult rhino. The scapular spine was very prominent and terminated below into an acromion process as elucidated by Mariappa (1986) in Indian elephant calf and a suprahamate process as mentioned by Ahasan *et al.* (2016) in Asian elephant, while Mariappa (1986) in Indian elephant calf mentioned it as uncinate process. Mahapatra *et al.* 2016) reported that the acromion process was absent in both calf and adult rhino.

On the middle part of the scapular spine, a well-developed curved (hook shaped) flattened process termed as suprahamate process was present, same as reported by Smuts and Bezuidenhout (1993) in African elephant. It was situated laterally and directed caudo-ventrally, while Ahasan *et al*. (2016) in Asian elephant reported that suprahamate process was situated medio laterally. At the middle of the scapular spine an elongated rough tuberosity, the tuber spine scapulae were present. On the contrary, Smuts and Bezuidenhout (1993) reported absence of tuber spine scapulae in African elephant.

In the medial or costal surface, a large subscapular fossa was present (Fig. 2) as described by Ahasan *et al.* (2016) in Asian elephant, Smuts and Bezuidenhout (1993) in African elephant, Mariappa (1986) in Indian elephant calf, Gupta and Deshmukh (2014) in camel. The sub-scapular fossa was divided into a caudal large and deep triangular fossa and a cranial smaller and shallow fossa due to the presence of a large raised linear column in agreement with Ahasan *et al.* (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant. However, the medial surface of scapula had undivided single subscapular fossa in camel (Lambate *et al*. 2009 and Gupta and Deshmukh 2014) but similar to the present study, Mahapatra *et al.* (2016) noted that the medial surface was divided into two unequal parts by well-developed serrated ridges transversally in Indian rhino.

In the proximal part of the medial surface two rough triangular areas were visible, called facies serrata. The cranial facies serrata was represented by a rough, convex triangular area with the apex towards the ventral angle as reported by Smuts and Bezuidenhout (1993) in African elephant. While the caudal triangular area was more or less smooth. However, Mariappa (1986) in Indian elephant calf mentioned that the costal surface of the bone was marked by a large rough quadrilateral area at the cranial angle and a narrow triangular area at the caudal angle.

The dorsal or vertebral border was formed by the union of lateral and medial surface towards the vertebral column. The dorsal border was convex and highest at the region of proximal part of scapular spine as mentioned by Mariappa (1986) in Indian elephant calf. The dorsal border formed an angular prominence at the level of the scapular spine as reported by Smuts and Bezuidenhout (1993) in African elephant. This prominence divided the dorsal border into a short, straight, cranial part near the cranial angle and a long slightly convex sloping caudal part towards the caudal angle. However, a thick, rough and convex dorsal border was reported in camel by Gupta and Deshmukh (2014) and by Sarma *et al.* (2003) in sambar deer.

Cranial border was second largest border of the scapula. It was almost straight and thin as noted by Sarma *et al.*

Fig. 3. Distal view of left scapula showing glenoid cavity (A), scapular collar (B), supra glenoid tubercle (C) and coracoid process (D).

Fig. 4. Medial view of left scapula showing glenoid cavity (A), scapular collar (B), supra glenoid tubercle (C), scapular notch (D) and coracoid process (E).

(2007) in Adult Asian elephant. However, Gupta and Deshmukh (2014) observed dorsal straight portion and ventral concave portion in camel.

Caudal border represented the shortest border of the scapula. The thick and rounded caudal border was gently concave towards the ventral angle as reported by Smuts and Bezuidenhout (1993) in African elephant, while Gupta and Deshmukh (2014) in camel noted a thick and nearly straight caudal border.

Cranial angle was formed by the fusion of dorsal border and cranial border. A small rough tuberosity was present in the obtuse cranial angle.

Caudal angle was formed by the fusion of dorsal border and caudal border. A large roughly triangular shaped tuberosity was present in this angle. Distal/glenoid angle on the hand was formed by the union of cranial and caudal border at the ventral aspect. It consisted of a well-developed glenoid cavity, supra glenoid tubercle (tuber scapulae) and a less developed coracoid process (Fig. 3).

The well-developed, cranio-caudally directed glenoid cavity was elliptical in shape (Fig. 3) and similar observations were noted by Ahasan *et al.* (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant. While Rohlan *et al.* (2017) in adult blue bulls observed that the glenoid cavity was oval in shape, Onwuama *et al*. (2021) reported ventrally concave glenoid cavity for humeral head articulation in West African giraffe. However, Jangir (2010) in chinkara elucidated that the shape of glenoid cavity was like heart of playing cards. Whereas, Ahasan *et al*. (2016) reported that the concavity of glenoid cavity was divided into a large medial and a small lateral articular surface by a saggital ridge in Asian elephant. The margin of glenoid cavity was surrounded by a band like structure called scapular collar (column scapulae). Similar observations were noted by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant.

Just above the glenoid cavity in the cranial and caudal part non-articular depressions were present. The cranial depression present just below the supra glenoid tubercle was shallow, while the caudal depression present in the ventral part of caudal border was deep and irregular (Fig. 3). Mariappa (1986) in Indian elephant calf mentioned that a concave area was present close to the caudal border of the glenoid cavity.

A small glenoid notch was present on the lateral margin of the rim (Fig. 4) which was in agreement with the findings of Sarma *et al*. (2007) in Adult Asian elephants and Gupta and Deshmukh (2014) in camel. Jangir (2010) in chinkara elucidated that a small glenoid notch was present on the cranio-medial margin of glenoid cavity, Rohlan *et al.* (2017) in adult blue bulls reported that a small glenoid notch was present over glenoid cavity and France (2009) in antelope noted a notch in the glenoid fossa. However, Lambate *et al*. (2009) in the scapula of adult camel recorded that glenoid notch was absent on the rim of the glenoid cavity.

A well-developed supraglenoid tubercle was present cranially and dorsal to the glenoid cavity (Fig. 4) as recorded by Ahasan *et al*. (2016) in Asian elephant, Sarma *et al.* (2007) in adult Asian elephant and Gupta and Deshmukh (2014) in camel. The tubercle was present in the ventral part of the cranial border, while Ahasan *et al*. (2016) in Asian elephant reported that this tubercle was present distal to the incisura scapulae.

A small coracoid process was present medial to the supraglenoid tubercle similar to the findings of Gupta and Deshmukh (2014). In agreement with the current study, Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant reported that the coracoid process was represented by the caudal ridge of the supraglenoid tuberosity. Lucy *et al*. (2018) in elephant and Pawan and Suraj (1999) in Neel gai recorded that the coracoid process was rudimentary.

In the present study, the flat and irregularly triangular shaped scapula weighed 14.56±0.21 kg and measured 79.55±0.54 cm in length and 68.90±0.43 cm in width (from

Table 1. Various gross parameters of Scapula of forelimb in Indian elephant

Scapula	Average
Weight (kg)	14.56±0.21 (13.94-15.20)
Maximum length (cm)	79.55±0.54 (78-81)
Maximum width from cranial border to caudal angle at costal surface (cm)	68.90±0.43 (67.5-70.1)
Length of caudal border of scapula (cm)	39.03±0.35 (38-40.1)
Length of dorsal border of scapula – straight (cm)	55.28±0.37 (54-56.1)
Length of dorsal border of scapula – curved (cm)	80.15±0.33 (79-81.1)
Length of cranial border of scapula (cm)	59.58±0.25 (58.7-60.2)
Length of glenoid cavity (cm)	18.78±0.43 (17.2-19.9)
Width of glenoid cavity (cm)	10.68±0.26 (9.8-11.3)
Depth of supraspinatus fossa (cm)	2.57±0.17 (2-2.9)
Width of supraspinatus part (cm)	8.42±0.17 (8-8.9)
Depth of infraspinatus fossa (cm)	3.47±0.11 (3-3.8)
Width of Infraspinatus part (cm)	37.70±0.22 (37-38.2)
Depth of subscapularis fossa (cm)	4.52±0.24 (3.6-5.0)
Width of subscapularis part (cm)	34.55±0.25 (34-35.1)
Length of spine (cm)	66.45±0.31 (65.3-67.3)
Free part of spine (acromion process) (cm)	10.45±0.33 (9-11.1)
Height of acromion process (cm)	15.70±0.23 (15-16.2)
Length of cranial rough triangular area (cm)	25.83±0.18 (25-26.2)
Cranial angle length (cm)	18.55±0.27 (17.5-19.1)
Caudal angle length (cm)	18.93±0.23 (18-19.5)
Supra glenoid tubercle – length (cm)	4.47±0.15 (4-4.8)
Supra glenoid tubercle – width (cm)	3.45±0.16 (3-3.9)
Coracoid process length (cm)	10.68±0.22 (10-11.2)
Coracoid process width (cm)	7.45±0.16 (7-7.9)

cranial to caudal angle) (Table 1). Similar parameters were reported by Lucy *et al.* (2018) in elephant as 76 cm and 64 cm and Sarma *et al*. (2007) in adult elephant of Assam as 57 cm and 55 cm, respectively. On the lateral aspect of scapula supraspinous fossa, infraspinous fossa and scapular spine were well-developed for better muscular attachment. At the middle of the scapular spine an elongated rough tuberosity was present. A large subscapular fossa present on medial surface was divided into a caudal large and deep triangular fossa and a cranial smaller and shallow fossa by a large raised linear column for giving better attachment of muscles on medial aspect. The well-developed glenoid cavity was elliptical in shape with smaller cranial and irregular caudal articular area. The margin of glenoid cavity was surrounded by a band scapular collar.

SUMMARY

The main objective of the work was to study gross and morphometry of the scapula of Indian elephant. The fore and hind limbs of the elephant were arranged in an almost vertical position under the body, similar to a pillar or leg of a table rather than being in the angular position seen in many other quadruped mammals to support great weight. The aim of this study was to elucidate the osteological outline on the bones of fore limb in Elephants. Three Indian elephants were used, along with some of the specimens available at the Department of Veterinary Anatomy, College of Veterinary Science and Animal Husbandry, Mhow. It was seen that scapula had two surfaces (lateral and medial), three borders (Cranial border, caudal border and dorsal border) and three angles (cranial, caudal and glenoid). The lateral surface was divided into two unequal fossa by a prominent scapular spine. The height of the scapular spine was lowest in the proximal part, but it increased towards the distal part, and was maximum towards near the acromion process. In the medial surface, a large subscapular fossa was present. The dorsal border was formed by the union of lateral and medial surfaces towards the vertebral column.

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