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Osteological Study on the Proximal row of Carpal Bones in Indian Elephant (*Elephas maximus indicus*)

P. J. KAPADNIS[1*], S. K. GUPTA[2], and S. K. KARMORE[3]
Department of Veterinary Anatomy and Histology
College of Veterinary Science and Animal Husbandry, NDVSU, Mhow, M.P.
Corresponding Author-Cattle Breeding Farm and Dangi Cow Research Station, MAFSU, Igatpuri

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ABSTRACT

The present study was conducted on the proximal row of carpal bones of fore limb in Indian elephant (*Elephas maximus indicus*). In the present study the short carpal bones were eight in number and were arranged in two rows. From medial to lateral side the proximal row consisted of radial, intermediate, ulnar and accessory carpals. The radial carpal was nearly small, truncated pyramid shaped bone. Proximally this bone was narrower than distally. It articulated proximally with the radius and distally with 1st and 2nd carpal bones of distal row. The ulnar carpal bone was the largest bone of the proximal row and roughly triangular in shape. The intermediate carpal bone was wedge shaped. The accessory carpal bone was falciform in shape and had only one articular surface which articulated with the posterior (palmar) surface of the ulnar carpal.

Keywords: Proximal, Carpal, Elephant, Forelimb.

INTRODUCTION

The elephant under the order of Proboscidea is a non-ruminant herbivore, belonging to the family Elephantidae with two living genera and species of elephants, *Elephas maximus*, of Southern Asia and *Loxodonta africana*, of Africa (Nowak,1999). The Asian elephants are subdivided into three different subspecies: *Elephas maximus maximus* of Sri Lanka, *Elephas maximus indicus* of Asia and *Elephas maximus sumatranus* of Sumatra (Shoshani and Eisenberg, 1982). The Indian elephant is native to main land Asia i.e. India, Nepal, Bangladesh, Bhutan, Myanmar, Thailand, Malay, Peninsula, Laos, China, Cambodia, and Vietnam, but regionally extinct in Pakistan (Choudhary *et al*., 2008). The government of India had notified a total of 32 Elephant Reserves in India (Source MoEF). .

Since 1986, the Asian elephant has been listed as endangered on the IUCN Red List as the wild population has declined by at least 50% since 1930 to 1940.The purpose of this work was to enhance the knowledge on elephant skeleton and the study on proximal row carpal bones of Indian elephant. It will overcome the gap of knowledge in the comparative anatomy. Also this study will provide a base line data for further vetero-legal, archaeological and clinical cases.

MATERIALS AND METHODS

For the present study material from three Indian elephants were used of either sex .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. 239/699826 on dated 29.12.2020.

Some of the specimens were available at the Department of Veterinary Anatomy, College of Veterinary Science and Animal Husbandry, Mhow. The skeletons were dug out from the grounds which were buried from last 5-10years in the premises of College of Veterinary Science and Animal Husbandry, Mhow. Subsequently, the specimens were sort out and cleaned in running tap water. These bones were washed out with bleaching powder to get rid of the offensive odour, dust and then sun dried afterwards for one week.

Various features of different proximal row carpal bones found in right and left forelimbs were recorded. The weight of each bone was taken by weighing machine and all the dimensions of each

1. Deputy Director Research, Cattle Breeding Farm and Dangi Cow Research Station, MAFSU, Igatpuri, 2. Associate prof., Department of Veterinary Anatomy and Histology, Mhow, 3. Professor, Department of Veterinary Anatomy and Histology, Jabalpur

*Corresponding Author: pj1kapadnis@rediffmail.com

carpal was taken with the help of inelastic thread and measuring tape and data were subjected to routine statistical analysis (Snedecor and Cochran, 1994).

RESULTS AND DISCUSSION

In the present study the short carpal bones were eight in number and were arranged in two rows in toto agreement with Mariappa (1986) in elephant calf, Smuts and Bezuidenhout (1993) in African elephant and Ahasan *et al*. (2016) in Asian elephant. From medial to lateral side the proximal row consisted of radial, intermediate, ulnar and accessory carpals. Akers and Denbow (2008) and Frandson *et al*. (2009) reported that the number of carpal bones varied between species. The horse had eight carpal bones, while ruminants had six carpal bones. Getty (1975), Konig and Liebich (2006) and Budras *et al*. (2009) reviewed that the carpus of the horse consisted of seven or eight bones arranged in two rows. Smuts and Bezuidenhout (1987) revealed that there were seven carpal bones in dromedary. Budras and Robert (2003) noted that in bovine the proximal row of carpal bones consists of radial, intermediate, ulnar and a thick, bulbous accessory carpal bone. Ingole *et al*. (2017) in Sahiwal cows, Onwuama *et al.* (2021) and Damian *et al*. (2012) in giraffe, Siddiqui *et al*. (2008) and Mahmud and Mussa (2016) in black Bengal goat found that six carpal bones were arranged in two rows, four in proximal and two in distal row. Jangir (2010) in Chinkara, Choudhary *et al*. (2015) in blackbuck, Bharti and Singh (2017) in blue bull, Pawan and Suraj (1999) in Neel gai and Rajani *et al.* (2019) in Indian Muntjac stated that the carpus consisted of six short bones arranged in two transverse rows one above the other.

The carpal bones were situated between the radius and ulna proximally and the metacarpal bones distally. The carpal bones were dissimilar to those of bovines and equines. They were proportionally much bigger same as reported by Damian *et al*. (2012) in giraffe. The carpal bones were block like as reported by Ramsay and Henry (2001) in elephant.

Radial Carpal

It was nearly a small, truncated pyramid shaped bone articulating above with the medial aspect of the distal end of the radius by small facet as mentioned by Mariappa (1986) in elephant calf.

The radial carpal bone was the most flattened and medial bone in the proximal row as elucidated by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant. It was placed obliquely in such manner that it faced medio-dorsally as reported by Smuts and Bezuidenhout (1993) in African elephant.

The small radial carpal bone consisted of 6 surfaces as reported by Getty (1975) in horse, Bharti and Singh (2017) in blue bull, Choudhary *et al*. (2015) in blackbuck and Choudhary *et al*. (2013) in chital. It was somewhat flattened anteroposterisoty, whereas Getty (1975) in horse recorded that it was compressed transversely. The anterior surface was rough and non-articular having numerous foramina in it (Fig.1). The medial surface was also rough and non-articular but having a triangular shaped fossa in the middle of this but Choudhary *et al*. (2013) in chital and Bharti and Singh (2017) in blue bull noticed slightly depressed with few foramina on this surface.

The posterior surface was non articular rough and having many irregular depression and concave in shape. Lateral surface was very small and irregular in shape. The proximal/dorsal surface was articular and consisted of two articular area of unequal sizes separated by a ridge. The dorsal articular area was articulating with radius bone while the smaller articular area was situated towards lateral side and articulating with the upper medial part of intermediate carpal bone.

The ventral surface was consisting of a large roughly oval shaped articular area for the articulation of 1st and 2nd carpal bones of distal row. However, Getty (1975) in horse recorded that distal surface articulated with the second and third carpal bones. In continuation with this large articular area, a small oval shaped articular area was present towards the lateral side for articulation with the lower medial part of intermediate carpal bone same as mentioned by Getty (1975) in horse. A large tuberosity was present towards the ventral part of the medial aspect of anterior surface; however Choudhary *et al*. (2013) in chital, Bharti and Singh (2017) in blue bull and Choudhary *et al*. (2015) in blackbuck mentioned that the caudal surface consisted of tubercles on its lower aspect.

Proximally the bone was narrower than distally. It articulated proximally with the radius same as reported by Smuts and Bezuidenhout (1993) in African elephant, Ahasan *et al*. (2016) in Asian elephant, Bharti and Singh (2017) in blue bull, Getty

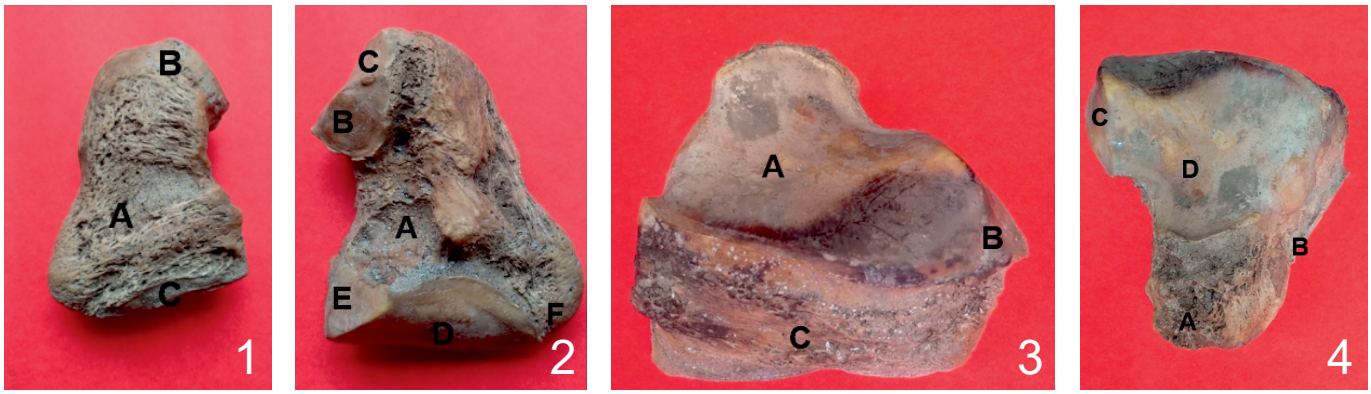

Fig. 1. Left radial carpal bone (anterior view) showing rough anterior surface surface having numerous foramina (A), proximal extremity (B) and distal extremity (C). **Fig. 2.** Left radial carpal bone (medial view) showing rough posterior surface (A), proximal/dorsal articular surface having dorsal large articular area (B), smaller articular area situated on lateral side (C), distal/ventral articular surface having large oval shaped articular area (D), small articular area towards lateral side (E), and a large tuberosity towards the medial aspect (F). **Fig. 3.** Wedge shaped left intermediate carpal (antero-dorsal view) showing proximal saddle shaped articular surface (A), small articular facet on dorso-lateral aspect (B) and rectangular shaped rough non articular anterior surface (C). **Fig. 4.** Left intermediate carpal (ventral view) showing distal saddle shaped articular surface having broader and slightly concave articular area on anterior side (A), narrow and deeply concave articular area on posterior side (B)

(1975) in horse, Smuts and Bezuidenhout (1987) in dromedary, Choudhary *et al*. (2013) in blackbuck, Choudhary *et al*. (2015) in chital and laterally by means of a proximal and distal facet with the intermediate carpal bone as reported by Getty (1975) in horse, Smuts and Bezuidenhout (1987) in dromedary and Bharti and Singh (2017) in blue bull. Distally it was articulated with the 2nd and 3rd carpal bones as described by Ahasan *et al*. (2016) in Asian elephant, Bharti and Singh (2017) in blue bull, Smuts and Bezuidenhout (1987) in dromedary, Choudhary *et al*. (2015) in blackbuck, Choudhary *et al*. (2013) in chital and Bharti and Singh (2017) in blue bull.

A relatively large space or canal occurred between the two articulations between the radial and intermediate carpal bones as recorded by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant.

In the present study weight of radial carpal was 174.25±1.89 g. The maximum length of medial and lateral borders on anterior side was 11.37±0.08 cm and 6.7±0.05 cm, respectively, while the maximum width at upper and lower part of this surface was 5.2±0.06 cm and 8.5±0.04 cm, respectively.

Intermediate carpal

The intermediate carpal bone was wedge shaped (Fig.3) with base facing dorsally same as recorded by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant, Getty (1975) in horse, Choudhary *et al*. (2013) in chital, Bharti and Singh (2017) in blue bull and Choudhary *et al*. (2015) in blackbuck, While it was rod-shaped in dromedary (Smuts and Bezuidenhout, 1987). It also had 6 surfaces. The anterior surface was rough, non-articular and rectangular in shape (Plate 3). The posterior surface was rough, non-articular and in the shape of rounded tuberosity, but Choudhary *et al*. (2013) in chital, Bharti and Singh (2017) in blue bull and Choudhary *et al*. (2015) in blackbuck noted a tubercle on its lower part. The rough medial surface had two articular facets one proximally and other distally for articulation with the radial carpal bone, same as reported by Getty (1975) in horse. The lateral surface was nearly similar in shape as medial surface and articulated with the medial surface of ulnar carpal bone, but the rough non articular area present on this surface was deep. It had a rounded tuberosity on the palmar aspect. Its proximal articular surface was saddle shaped (Plate3) and articulated with the radius same as reported by Getty (1975) in horse, Choudhary *et al*. (2013) in chital, Bharti and Singh (2017) in blue bull and Choudhary *et al*. (2015) in blackbuck. Dorsolaterally an oblique continuation of this surface also articulated with the ulna and with the ulnar carpal bone as recorded by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant. Along the distal border of the lateral surface a parallel area occurred for articulation with the contiguous surface of the ulnar carpal bone.

The distal articular surface was also saddle shaped like the proximal, but the curvatures were more pronounced (Plate 4). The articular area of

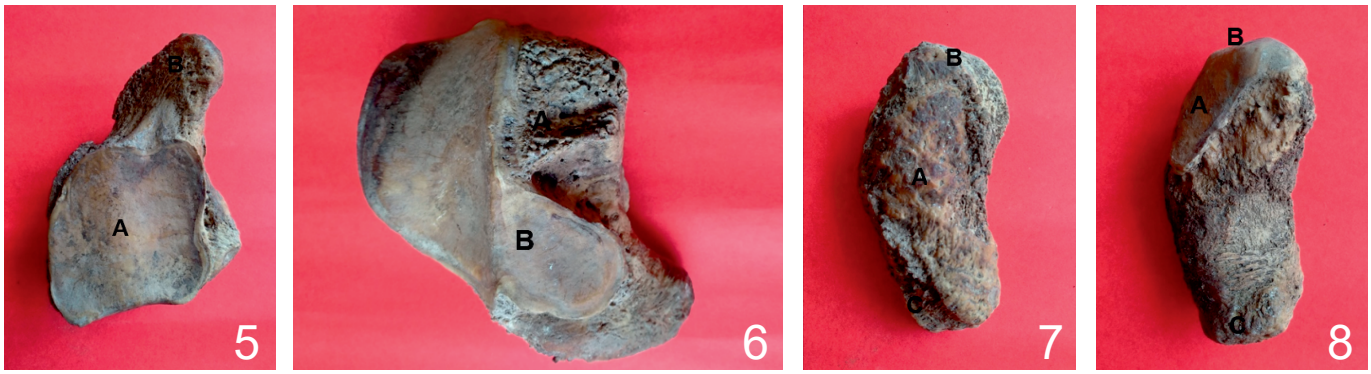

Fig. 5. Left ulnar carpal (ventral view) showing quadrilateral shaped distal articular area on medial side (A) and non-articular projection on lateral side (B) . **Fig. 6.** Left ulnar carpal (posterior view), rough and non-articular medial part of posterior surface (A), large oval shaped articular area on lateral part (B) of posterior surface. **Fig. 7.** Left accessory carpal (posterior view) showing rough non articular surface (A), proximal extremity (B), groove in the tuberous projection (C). **Fig. 8.** Right accessory carpal (anterior view) showing large oval shaped articular area (A) on anterior side, small articular area (B) on antero-dorsal aspect in the proximal end and a non-articular tuberous projection (C).

anterior side was broader and slightly convex in shape, while the articular area of posterior side was narrow about half the length of anterior side and deeply concave in shape. It articulated with the 3rd carpal bone in agreement with Smuts and Bezuidenhout (1993) in African elephant, while Getty (1975) in horse reported that it articulated with the third and fourth carpal bones. However,Choudhary*et al*. (2013) in chital, Bharti and Singh (2017) in blue bull and Choudhary *et al*. (2015) in blackbuck reported that medial articular facet of this surface articulated laterally with the proximal surface of second and third fused carpal bone.

In the present study weight of intermediate carpal was 408.96±1.68 g. The length of anterior border, posterior border, medial border and lateral border on proximal articular surface of intermediate carpal was 9.53±0.12 cm, 3.5±0.1 cm, 5.37±0.17 cm and 8.1±0.08 cmrespectively, while the length of anterior border, posterior border, medial border and lateral border on its distal articular surface was 8.87±0.05 cm, 2.77±0.11 cm, 8.18±0.12 cm and 8.62±0.06 cmrespectively. On anterior side the maximum length and width (height) were 9.9±0.04 cm and 6±0.06 cm, respectively. On posterior side the maximum length and width (height) were 4.01±0.10 cm and 5.23±0.16 cm, respectively.

Ulnar carpal

The ulnar carpal bone was the largest bone of the proximal row and was situated on the lateral side. It was roughly triangular in shape with a prominent elongation pointing palmarly and laterally (Plate 5) same as recorded by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant, while Getty (1975) in horse mentioned that it was smallest and most irregular bone. Also, Choudhary *et al*. (2013) in chital, Choudhary *et al*. (2015) in blackbuck and Bharti and Singh (2017) in blue bull reported that it was irregular in shape. On the posterior (palmar)surface of the base of the projection a large oval articular facet was present for articulation with the accessory carpal bone same as found in horse (Getty, 1975), chital (Choudhary *et al*., 2013), blackbuck (Choudhary *et al*., 2015) and blue bull (Bharti and Singh, 2017). The proximal articular surface was convexo- concave in shape antero-posteriorly. The distal surface consisted of a quadrilateral shaped articular area on medial side and a flattened, non-articular projection on lateral side as recorded by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant and more or less similar as reported byChoudhary*et al*. (2013) in chital, Choudhary *et al*. (2015) in blackbuck and Bharti and Singh (2017) in blue bull. However, in horse it was oblique and undulating (Getty, 1975) and in dromedary it was noted as saddle shaped (Smuts and Bezuidenhout, 1987). On medial aspect it articulated with the intermediate carpal bone while a small, elongated facet facing ventro-palmarly articulated with the 5th metacarpal bone. The anterior surface was rough, non-articular and continued with the lateral surface of same type (Plate 6). In the medial surface small, elongated articular area was present proximally and distally for articulation with the same type articular areas present on the lateral surface of intermediate carpal bone (Plate 20). The distal articular area present in medial surface was slightly larger in size than the proximal articular area. The medial part of posterior

surface was very much irregular and having numerous foramina, while on its lateral part an oval shaped large articular area was present for articulation with the accessory carpal bone.

In the present study, weight of ulnar carpal was 601.33±2.30 g. The length of anterior border, posterior border, medial border and lateral border on its proximal articular surface was 6.77±0.08 cm, 8.33±0.13cm, 5.85±0.06cm and 7.85±0.06 cm respectively, and length of anterior border, posterior border, medial border and lateral border of distal articular surface was 7.65±0.05 cm, 6.52±0.02 cm, 6.92±0.02 cm and 6.10±0.03 cm respectively.

The maximum length and width (height) of anterior surface was 8.55±0.06cm and 5.2±0.09 cm respectively, while the maximum length and width (height) on posterior surface was 12.20 ±0.12 cm and 7.53±0.07cm, respectively .

Accessory carpal

It articulated with the posterior (palmar) surface of the ulnar carpal (Plate 7) and with the ulna same as elucidated in Asian elephant by Ahasan *et al*. (2016) and in African elephant by Smuts and Bezuidenhout (1993). The rest of the non-articular surfaces were rough and contain numerous small vascular foramina as reported in Asian elephant (Ahasan *et al*. 2016) and in African elephant (Smuts and Bezuidenhout 1993). In present study accessory carpal bone was falciform (long and narrow) in shape while it was discoid in horse (Getty, 1975) and short in blue bull (Bharti and Singh, 2017), chital (Choudhary *et al*., 2013) and blackbuck (Choudhary *et al*., 2015). It has large oval shaped articular area on its anterior side for articulation with the palmar (posterior) surface of ulnar carpal bone (Plate 8) same as reported in blue bull (Bharti and Singh, 2017), chital (Choudhary *et al*., 2013) and blackbuck (Choudhary *et al*., 2015).A small oval articular area in continuation with large one was present on antero-dorsal aspect for articulation with the styloid process of ulna same was reported by Smuts and Bezuidenhout (1987) in dromedary.An elongated tuberous process from its articular base projected caudally (palmarly) in a ventro-medial direction. There was a smooth transverse groove along the medial surface of this projection as reported in horse (Getty,1975). The rest of the non-articular surfaces were rough and contained numerous small vascular foramina as elucidated by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant.

In the present study weight of accessory carpal was 254.85±3.40g.The maximum length, width and thickness of this falciform shaped bone was 13.10±0.14 cm, 6.20±0.06 cm and 4.10±0.04 cm, respectively. The maximum length and width of large oval shaped articular surface present in anterior aspect of this bone was 5.50±0.04 cm, and 3.42±0.04 cm, respectively.

REFERENCE

Ahasan, A.S. M.L., Md. AbulQuasem, A. S. M., Rahman, M.R., Hasan, R.B., GolamKibria, A. S. M. and Shil, S. K. 2016. Macroanatomy of the bones of thoracic limb of an Asian elephant *(Elephasmaximus). International Journal of Morphology*, 34 : 909-917.

Akers, R. M. and Denbow, M. 2008. *Anatomy and Physiology of Domestic Animals*.1st Edn., Blackwell Publishing, Ames, Iowa, pp: 152-160.

Bharti, S. K. and Singh, I. 2017. Morphological and morphometrical studies on the carpal bone of blue bull (*Boselaphustragocamalus). Indian Journal of Animal Research*, 52 : 632-636.

Budras, K. D. and Robert, E. 2003. *Bovine Anatomy: An Illustrated Text*, First Edition Schlutersche, pp: 2-3.

Budras, K. D. Sack, W.O and Rock, S. 2009. *Anatomy of the Horse: An Illustrated Text*, Fifth Edition Schlutersche, pp: 4

Choudhary, A. L., Choudhary, D. K., Desai, A., Duckworth, J. W., Easa, P. S., Johnsingh, A. J. T., Fernando, P., Hedges, S., Gunawardena, M., Kurt, F., Karanth, U. ,Lister, A., Menon, V., Riddle, H., Rubel, A., and Wikramanayake, E. 2008. (IUCN SSC Asian Elephant Specialist Group) "Elephas maximus". IUCN Red list of threatened species.

Choudhary, O.P., Mathur, R., Joshi, S., Beniwal, G. and Dangi, A. (2013).Gross and biometrical studies on carpals of chital *(Axis axis). Veterinary Practitioner,* 14 : 36- 39.

Choudhary, O.P., Singh, I. and Bharti, S.K. (2015). Morphometrical studies on the carpal bones of Indian blackbuck *(Antilopecervicapra). International Journal of Basic and Applied Agricultural* Research, 13 : 457-461.

Damian, A., Gudea, Al., Irimescu, I.,Blendea, A.,Chirilean, I., Stan, F., Crisan, M., Dezdrobitu, C. and Ciama, I. 2012. Comparative studies of the thoracic appendicular skeleton in the giraffe and in the cow. *lucrari Stiintifice Medicina Veterinara,* 14 : 5-12.

Frandson, R.D. Wilke, W.L. and Fails, A.D. 2009**.** *Anatomy and Physiology of Farm Animals*. 7th Edn., Wiley-Blackwell, Philadelphia. pp 71-74.

Getty, R. 1975. Equine and ruminant osteology In: Sisson and Grossman's. *The Anatomy of the domestic Animals*. (R. Getty Edn.) Vol. I, 5th Edn. W.B. Saunders Company, Philadelphia. pp. 273-317, 318-348, 1231-1252.

Ingole, S.P., Chaurasia, D. and Deshmukh, S.K. 2017.Gross morphometrical study on the skeleton of forelimb of Sahiwalcows. In: XXXII Annual Convention and National Symposium on Advances and Applications of Veterinary Anatomy in Livestock, Pet, Poultry, Lab. Animal and wildlife, Bhubaneswar, 21-23 December 2017. Indian Association of Veterinary Anatomists. pp 21.

Jangir, D.K. 2010. Gross studies on the bones of the forelimb in Indian gazelle *(Gazellagazellabennettii*). M.V.Sc thesis (Veterinary Anatomy and Histology), Rajasthan University of Veterinary and Animal Sciences, Bikaner.

Konig, H.E. and Liebich, H.G. 2006. Veterinary *Anatomy of Domestic Animals*, 3rd Edn., Schattauer, Stuttgart Germany, pp: 49-104, 145-164, 215-236.

Mahmud, A. A. Md. and Mussa, T. Md. 2016. Comparative macro anatomy of forelimb bones of black Bengal goat and indigenous dog: An over View. *American Journal of Agricultural Science, Engineering and Technology.* 3 : 45-55.

Mariappa D. (1986). *Anatomy and histology of the Indian elephant*. Indira publishing house P.O.Box 37256, Oak Park, Michigan U.S.A pp 17-21.

Nowak, R. M. 1999. *Walker's Mammals of the World.* 6th Edn. Baltimore, Johns Hopkins University Press.

Onwuama, K.T., Kigir, E.S., Jaji, A.Z. and Salami, S.O. 2021.Gross anatomical studies on the fore limb of the West African giraffe *(GiraffaCamelopardalis Peralta)*. *Journal of Veterinary Anatomy,* 14 : 13 - 23

Pawan, K. and Suraj, K. 1999.Morphology of the bones of a Neel gai (Boselaphustrago camelus). *Indian Journal of Veterinary Anatomy*, 11 : 103-114.

Rajani, C.V., Chandy, G., Sankunny, M., Surjith, K., Patki, H.S. and Ashok, N. 2019. Morphological identification of pectoral limb bones of Indian Muntjac *(Muntiacusmuntjak)* from domestic ruminants. *Indian Journal of Animal* Research, 53 : 218-221.

Ramsay, C.E. and Henry R. W. 2001. Anatomy of the elephant foot. The elephant's foot-prevention and care of foot conditions in captive Asian and African elephants. Eds Csuti, B., Sargent E.L.andBechert, U.S.1st edition Iowa State University Press, Ames,Iowa.pp 9-12

Shoshani, J. and Eisenberg, J.F. (1982). "Elephasmaximus" . *Mammalian Species (182) : 1–8.* doi:10.2307/3504045. JSTOR 3504045.

Siddiqui, M.S.I. Khan, M.Z.I., Sarma, M., Islam, M.N. and Jahan, M.R. 2008. Macro-anatomy of the bones of the limb of Black Bengal goat *(Capra hircus*). *Bangladesh Journal of Veterinary Medicine*, 6 : 59–66.

Smuts, M. and Bezuidenhout A.J. 1993. Osteology of the thoracic limb of the African elephant *(Loxodonta Africana).Onderstepoort Journal of Veterinary Research*, 60 : 1-14.

Smuts, M. and Bezuidenhout, A.J. 1987. *Anatomy of the Dromedary*. Clarendon Press, Oxford, UK. pp: 24-47

Snedecor, G.W. and Cochran,W.G. 1994. Statistical Methods. 8th Edn., Iowa State University Press, Ames, Iowa USA.