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Morphological and Morphometrical Study on the Distal Row of Carpal Bones in Indian Elephant (*Elephas maximus indicus*)

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ABSTRACT

The fore and hind limbs of the elephant are arranged in almost vertical position under the body, similar to a pillar or leg of table rather than being in the angular position seen in many other quadruped mammals to support great weight. The aim of this study is to elucidate the morphological outline on the carpal bones of Elephants, thereby making more contribution in filling the gap of knowledge and skills framework in this field. The short carpal bones were eight in number and were arranged in two rows**.** The distal row consisted of first, second, third and fourth carpal bones. The first carpal bone of the distal row was a smallest bone. The 3rd carpal bone was almost quadrilateral shaped. Fourth carpal forms the lateral component of the distal row.

Key Words: Distal, 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, Th ailand, Malay,Peninsula, Laos, Cambodia, China 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). The total elephant population in India is 27312 (Latest Census in 2017). 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 carpal bones of Indian elephant will overcome the gap of knowledge in the comparative anatomy. Also this study provides a baseline data for further vetero-legal, archaeological and clinical cases.

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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 no239/6998261on 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 5-10 years 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.

After collection and sorting of all the bones, desire bones were kept in separate boxes. The gross study was carried out in osteology laboratory, Department of Veterinary Anatomy, College of Veterinary Science and Animal Husbandry, Mhow. Various morphological features of different distal row carpal bones found in right and left fore limb

were recorded. The weight of each bone was taken by weighing machine and all the dimensions of each 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

The distal row of carpus in the forelimb of elephant was consisted of four carpals, from medial to lateral side these were I, II, III and IVth carpals.

Os-Carpale -I (C1)

The first carpal bone of the distal row was a flattened roughly quadrilateral and smallest bone (Fig. 1) in contrast to the more bulky form of the others as elucidated by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant but it was absent in horse Getty (1975). It projects medially and was pointed distopalmarly as mentioned by Smuts and Bezuidenhout (1993) in African elephant. Its medial surface was more or less flattened and rough while the lateral surface was more concave and contains numerous nutrient foramina as elucidated by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant. The medial border was thick and concave while the lateral border was comparatively thin and convex (Fig. 2).

Proximally a large slightly concave rectangular shaped facet was present for articulation with the same type of facet of os-Carpale–II. Proximally in continuation of the antero-lateral aspect of this large facet a smaller roughly triangular shaped slightly concave articular facet was present for the articulation of proximal medial facet of 2nd metacarpal bone as mentioned by Smuts and Bezuidenhout (1993) in African elephant. The distal articular surface was convex and oval in shape and articulates with the concave oval shaped articular part of 1st metacarpal bone as noted in African elephant by Smuts and Bezuidenhout (1993). On lateral and medial aspect of this end rough tuberosities were present. The lateral tuberosity was larger in comparison to medial one.

In the present study weight of carpal C1 was 117.76±0.47 g. It was 7.0±0.41 cm in length, 6.5±0.27 cm in width and 3.0±0.17 cm in thickness. The length of anterior border, posterior border, medial border and lateral border of proximal articular surface of C was 3.57±0.18cm, 3.92±0.21cm, 2.06±0.04cm and3.07±0.06 cm, respectively, while the maximum length and width of oval articular area of distal surface was 5.0±0.18cm and 3.0±0.10 cm, respectively.

Os-Carpale -II (C2)

This was the 2nd smallest of the carpal bones as reported in African elephant by Smuts and Bezuidenhout (1993), in dromedary by Smuts and Bezuidenhout (1987) and in horse by Getty (1975) and it was roughly triangular in shape with a blunt palmar projection on the posterior aspect as elucidated by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant. Lateral surface of this bone was very irregular and dorso-ventrally articulated with the medial surface of 3rd carpal bone by means of a large antero- posteriorly convexo-concave curved bifurcated area in upper part (Fig. 3) and by a small elongated faced on lower part as reported in horse ,Getty (1975). In between the upper and lower articular area, the remaining portion of this surface was rough and excavated. The broad anterior surfaces was rough and present numerous foraminous (Fig. 4) as reported by Smuts and Bezuidenhout (1993) in African elephant, while the posterior surface was narrow, rough and had a well-developed tuberosity.

The flattened proximal part articulates with the distal articular part of the radial carpal as reported by Smuts and Bezuidenhout (1993) in African elephant and Smuts and Bezuidenhout (1987) in dromedary. The distal area was roughly T-shaped as noted by Smuts and Bezuidenhout (1993) in African elephant. It articulated with part of the 2nd metacarpal bone, while about half of the medial surface of the bone consisted of a quadrilateral facet for the 1st carpal. However, in dromedary mediodorsally there were two facets for C3 and distally it rests on Mc-III (Smuts and Bezuidenhout, 1987). But in horse the distal surface

was articular and consisted of a large, flattened facet for the second or inner metacarpal bone, and a small one for the third or large metacarpal bone some specimens have a small facet on the lower part of the volar surface for articulation with the first carpal bone Getty (1975). In the present study weight of carpal C2 was 181.37±0.87 g. The length and width (height) of rough anterior surface was 6.0±0.07 cm and 5.5±0.06 cm, respectively.

Os-Carpale -III (C3)

The 3rd carpal bone was almost quadrilateral (cuboidal) shaped (Fig. 5), however square shaped carpal bone was observed by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant. It was consisted of six (6) surfaces. The proximal /dorsal articular surface was saddle shaped. Its (dorsal articular surface) anterior half part was flattened while the posterior half part was convex in shape, for articulation with the distal (ventral) part of intermediate carpal bone as described by Ahasan *et al*. (2016) in Asian elephant, Smuts and Bezuidenhout (1993) in African elephant and Smuts and Bezuidenhout (1987) in dromedary. The distal / ventral articular surface was divided by a sagittal ridge into a small medial and a large lateral area (Fig. 6) for articulation with the dorsal aspect of 2nd and 3rd metacarpal bones, respectively same as described by Ahasan *et al*. (2016) in Asian elephant Smuts and Bezuidenhout (1993) in African elephant and Getty (1975) in horse. The anterior non-articular surface was flattened rough with numerous foramina. The posterior (palmar) non-articular, rough surface was broad and flat proximally (in upper part) and bears a prominent tuberosity distally (towards ventral side). The medial surface was characterised by a deep, rough non-articular central concavity with numerous foramina as reported in African elephant by Smuts and Bezuidenhout (1993). In the upper part of this surface a large articular area was present, which was broader in anterior aspect and narrower in posterior aspect. While the lower part of this surface had a thin elongated area. The medial surface of this bone was articulating with the lateral surface of 2nd carpal bone.

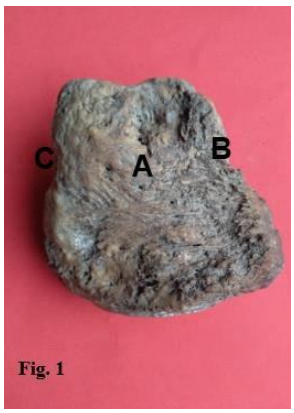
The lateral surface of this bone has a rough, non-articular central concavity with numerous foramina however; in African elephant Smuts and Bezuidenhout (1993) noted this on dorsal surface particularly towards extremities. In the upper part of this surface an extensive flask shaped articular area was present. This articular area was broader towards posterior side. While the lower part of this surface has a small, elongated area. This surface articulates with the medial surface of the 4th carpal bone. In the present study weight of carpal C3 was 603.45±2.23g.The length of anterior, posterior, medial and lateral borders of proximal surfaces were 9.01±0.21cm, 9.10±0.17cm,6.08±0.15cm and 6.12±0.18cm, respectively and the length of anterior, posterior, medial and lateral borders of distal surface were 7.0±0.10cm, 5.5±0.11cm, 6.1±0.12cm and 6.5±0.14 cm, respectively. The anterior surface had the maximum length of upper and lower part as 8.5±0.05 cm and 6.1±0.19 cm respectively, while it had a width (height) of 7.5 ±0.25cm. The non-articular roughly triangular shaped posterior surface had a length of upper and lower part as 8.1±0.14 cm and 3.2±0.11 cm, respectively, while it had a width (height) of 8.13±0.15 cm.

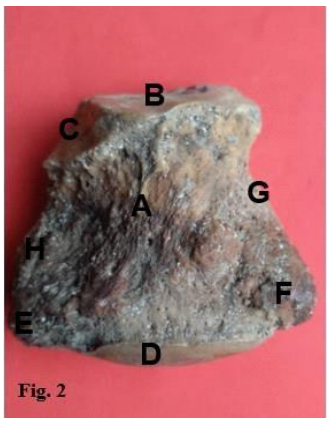
Os-Carpale-IV (C4)

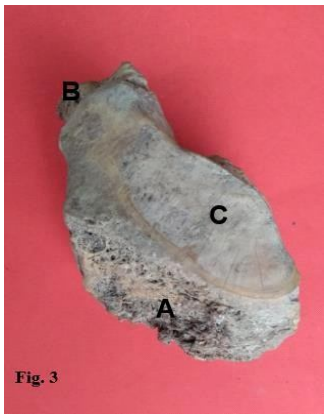
This bone forms the lateral component of the distal row. Its proximal articular surface was for the ulnar carpal bone (Fig. 7) while the distal articular surfaces accommodate part of the 3rd metacarpal and metacarpals 4 and 5 same as described by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant. However, Getty (1975) in horse, Choudhary *et al*. (2013) in chital, Bharti and Singh (2017) in blue bull and Choudhary *et al*. (2015) in blackbuck noted that this divided proximal surface articulated with the intermediate and ulnar carpal bones. Smuts and Bezuidenhout (1987) in dromedary reported that the proximal surface did not articulate with intermediate carpal, but completely articulated with the ulnar carpal.

The proximal / dorsal articular surface was saddle shaped (Fig. 8) nearly same as in 3rd carpal bone. Same was reported by Smuts and

Bezuidenhout (1987) in dromedary. The distal / ventral articular surface was in the form of 'U' shape with a notch on anterior aspect. The anterior non-articular surface was roughly quadrilateral in shape, rough and having numerous foramina. This anterior surface was continued with the lateral surface without clear cut demarcation. Laterally the bone was narrow and elongated in shape and presents a rounded tuberosity towards the ventral aspect of anterior side. The posterior / palmer surface was roughly triangular shape with many large vascular foramina towards the proximal articular surface. The medial surface of this bone was nearly same as the lateral surface of the 3rd carpal bone. The upper and lower parts of this surface were articular whereas the middle portion was concave, non-articular, rough and having numerous small foramina. The upper articular part of this surface was extensive flask shaped same as found in 3rd carpal bone and the lower articular area was elongated shaped but bigger than the same area of 3rd carpal bone.In the present study weight of carpal C4 was 621.95±3.36 gm. The length of anterior,







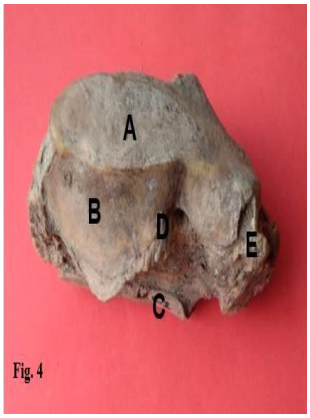
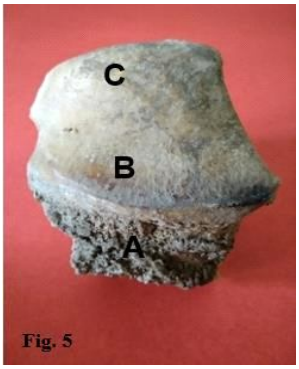
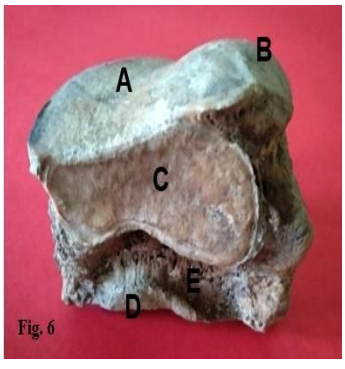
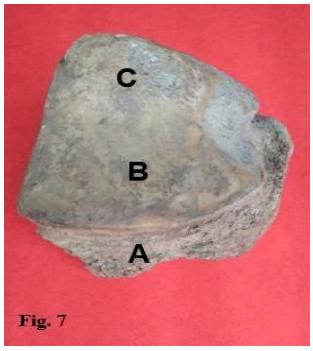


Fig. 1. Left C1-first carpal (anterior view) quadrilateral shaped bone having rough medial surface(A), concave medial border(B) and convex lateral border (C).**Fig. 2**. Left C1-first carpal (posterior view) lateral surface with foramina (A), proximal articular area having rectangular shaped large facet(B), small triangular shaped facet (C) in the antero-lateral aspect, distal extremity having convex and oval shaped articular area (D), lateral tuberosity(E), medial tuberosity(F), body part showing concave medial border(G) and convex lateral border(H).**Fig. 3.** roughly triangular in shape left C2(dorso anterior view), having rough and broad anterior surface(A), blunt palmar projection on the posterior aspect (B) and flattened proximal articular area (C).**Fig. 4.** Left C2 (dorso-lateral view) showing proximal articular area (A) with irregular lateral surface having large antero- posteriorly convexo-concave articular area at upper part (B), small, elongated facet at lower part (C), rough and excavated non-articular area(D) and blunt palmar projection on the posterior aspect(E).







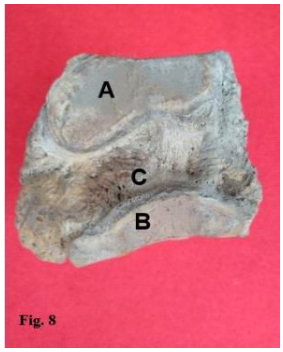


Fig. 5. Quadrilateral (cuboidal shaped) left C3 (antero-dorsal view) showing anterior surface with numerous foramina (A), saddle shaped proximal surface having flattened anterior part (B) and convex posterior part (C).**Fig. 6.** Left C3(dorso lateral view) showing saddle shaped dorsal surface (A), posterior surface(B) and lateral surface having flask shaped articular area on upper part (C), small elongated articular area in lower part (D) and rough central concavity with foramina(E).**Fig. 7.** Quadrilateral (cuboidal shaped) left C4 (antero-dorsal view) showing anterior surface with numerous foramina (A), saddle shaped proximal surface having flattened anterior part (B) and convex posterior part (C)**Fig. 8.** Left C4 (dorso- medial view) showing medial surface having flask shaped upper articular part (A), elongated lower articular area(B), and middle non-articularportion with foramens (C).

respectively and the length of anterior, posterior, medial and lateral borders of distal surface were 8.5±0.16cm, 8.0±0.15cm, 7.5±0.13cm and 6.5±0.18 cm, respectively. The lengths of dorsal, ventral, medial and lateral borders of anterior surface were 8.0±0.10 cm, 7.0±0.15 cm, 8.0±0.18 cm and 6.0±0.13 cm, respectively. The lateral surface had a length of 10.1±0.11 cm and width of 5.5±0.15 cm. The non-articular roughly triangular shaped posterior surface had a length of upper and lower part as 10.1±0.15 cm and 2.1±0.14 cm, respectively, while it had a width (height) of 10.13±0.17 cm. The comparative size of the distal carpal bones were IV>III>II>I from the largest to the smallest as recorded in Asian elephant by Ahasan *et al*. (2016) and in horse by Getty (1975). However, Getty (1975) mentioned that in cattle the distal row was consisted of two bones only, because the first carpal bone was absent, second and third carpal fused and fourth one was single. While Choudhary *et al*. (2013) in chital, Bharti and Singh (2017) in blue bull and Choudhary *et al*. (2015) in blackbuck noted that these two bones of the distal row were smaller. From the present study it is concluded that the short carpal bones were eight in number and were arranged in two rows. The distal row consisted of four carpus. From medial to lateral side the distal row consisted of carpal 1, carpal 2, carpal 3 and carpal 4. The fourth carpal was largest and first one was smallest

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