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Morphological Studies on the Metacarpals of Indian Elephant (*Elephas maximus indicus*)

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ABSTRACT

Background: The fore and hind limbs of the elephant 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. The aim of this study was to elucidate the morphological and morphometrical outline on the metacarpals in Elephants, thereby making more contribution in filling the gap of knowledge and skills framework in this field.

Methods: For the present study, the material from three Indian elephants were used. Some of the specimens were available at the Department of Veterinary Anatomy, Mhow. Few skeletons were dug out from the ground which were buried from the last 5-10 years in the premises of college.

Result: There were five metacarpal bones lying between the carpal bones (above) and the digits (below). Metacarpals were long bones and each metacarpal consisted of a shaft and two extremities *i.e.*, proximal and distal extremely. The 3rd metacarpal bone was the longest and well developed, while the 2nd and 4th metacarpals were almost equal in length and slightly shorter than the 3rd one.

Key words: Indian elephant, Metacarpals, Morphology, Morphometry.

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 India and *Elephas maximus sumatranus* of Sumatra (Shoshani and Eisenberg, 1982). As the elephant is the largest living terrestrial mammal, the feet have to carry an enormous weight and hence feet are probably one of the most important parts of its body. Many numbers of captive Asian elephants suffer from numerous foot ailments as a result of being tethered in unhygienic surroundings and these conditions often aggravate due to negligence and lack of awareness regarding proper care and treatment among elephant keepers. Hence an observational study of the elephants of this region was warranted.

The purpose of this work was to enhance the knowledge on elephant skeleton and the study on metacarpals 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.

MATERIALS AND METHODS

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 239/699/8261 on dated 29.12.2020.

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Some of the specimens were available at the Department of Veterinary Anatomy, Mhow. The skeletons were dug out from the grounds which were buried from the last 5-10 years in the premises of college. Subsequently, the specimens were sort out and cleaned in running tap water.

After collection and sorting of all the bones, desired bones were kept in separate boxes. Various osteological features of different metacarpals found in right and left forelimb were recorded. The present work was carried out at Department of Veterinary Anatomy, College of veterinary science and Animal Husbandry, NDVSU, Mhow (M.P.) during the Jan 2021 to Jan 2022.

RESULTS AND DISCUSSION

There were five metacarpal bones lying between the carpal bones (above) and the digits (below) same as reported by

Ahasan *et al.* (2016) in Asian elephant, Smuts and Bezuidenhout (1993) in African elephant and Mariappa (1986) in Indian elephant. Nurhidayat *et al.* (2015) in Sumatran rhino reported four metacarpal bones. However, Ingole *et al.* (2017) reported that in Sahiwal cows the metacarpal comprised of two metacarpal bones (one large and one small) in each forelimb. The large metacarpal bone consisted of fused III and IV metacarpal bones as reported by Smuts and Bezuidenhout (1987), Redah and Hussin *et al.* (2016) and Singh *et al.* (2017) in dromedary, Bharti *et al.* (2020) in blue bull, Budras *et al.* (2003) in bovine, Konig and Liebich (2006) in domestic animals, Akers and Denbow (2008) in ruminants, Choudhary *et al.* (2014) in chital, Rajani *et al.* (2019) in Indian Muntjac, Choudhary and Singh (2016a) in blackbuck and Jangir *et al.* (2012) in chinkara.

Chinkara had two small metacarpals; metacarpal II and metacarpal V (Jangir *et al.*, 2012) and cattle had only one small metacarpal bone (metacarpal V) (Getty, 1975 and Konig and Liebich, 2006). But Getty (1975), Konig and Liebich (2006), Akers and Denbow (2008), Budras *et al.* (2009) and Frandson (2009) reported the presence of one large metacarpal bone namely metacarpal III and two splint bones namely metacarpal II and IV in horse. Damian *et al.* (2012) and Onwuama *et al.* (2021) in giraffe, Siddiqui *et al.* (2008) and Mahmud and Mussa (2016) in black Bengal goat mentioned only the large metacarpal bone.

Metacarpals were long bones and each metacarpal consisted of a shaft and two extremities *i.e.*, proximal and distal as mentioned by Ahasan *et al.* (2016) and Smuts and Bezuidenhout (1993) in elephant, Onwuama *et al.* (2021) and Damian *et al.* (2012) in giraffe and Getty (1975) in horse.

The 3rd metacarpal bone was the longest and well developed, while the 2nd and 4th metacarpals were almost equal in length and slightly shorter than the 3rd one. The 1st metacarpal was the shortest among all the metacarpals, while the 5th metacarpal was longer than 1st but shorter than 2nd, 3rd and 4th metacarpal bones. While Ahasan *et al.* (2016) in Asian elephant reported that the III > IV > II > V> I. They all represent typical features of metacarpal bones *viz.* an elongated shape and an approximately quadrilateral diameter. The same was reported by Smuts and Bezuidenhout (1993) in African elephant. Metacarpals I, II, III and IV were the most oblique and metacarpal V was the most vertical same as observed by Ahasan *et al.* (2016) in Asian elephant.

The first metacarpal bone (MC-1) was the smallest and most medial bone. At the Proximal extremity it had a large oval and elongated shaped concave articular area for the articulation with the first carpal bone. There was no articulation with MC-2. Medio-palmarly the base was expanded to form a prominent palmar tuberosity. The body was slightly constricted towards its middle same as reported in African elephant by Smuts and Bezuidenhout (1993).

The dorsal, lateral and ventral surfaces of the body were continuous. The lateral surface was slightly concave, while the medial surface was flat and rough. The medial border was thin and proximally attached with large sized palmer tuberosity (Plate 1 and 2). Proximally on its dorso-lateral and ventro-medial aspects small metacarpal tuberosity was present. The proximal part of the body expands to form roughened surfaces dorsally and, on each side, while the distal expanded part of body was convex on dorsal aspect and slightly concave on ventral aspect with irregular surface for the attachment of ligaments as recorded in African elephant by Smuts and Bezuidenhout (1993). The distal extremity consisted of a broad and roughly rounded area. At this extremity the trochlea presents two articular areas which were divided by a transverse line. The dorsal small articular area articulates with the single tusk like phalanx while the palmar facet with a trochlea shaped elongated, smooth articular surface along its posterior part was for

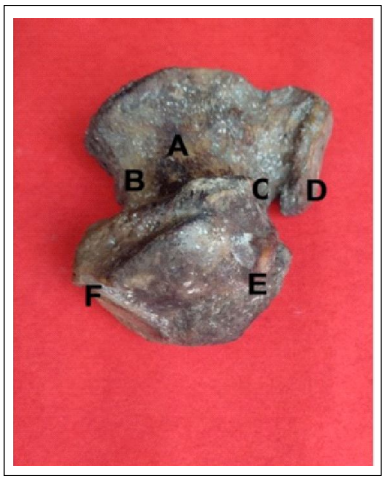


Plate 1: Left metacarpal 1 (posterior view), showing posterior surface (A), concave lateral surface (B), thin medial border (C), palmar tuberosity (D), distal extremity with small articular area (E) and large trochlea shaped articular area (F).

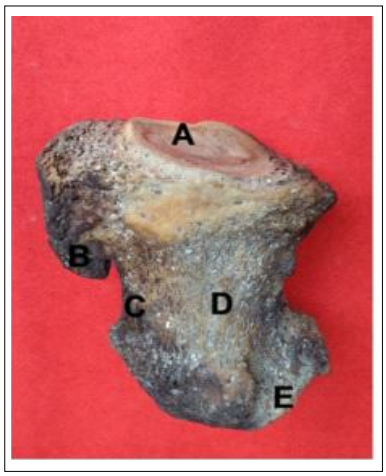


Plate 2: Left metacarpal 1 (dorso-anterior view) showing oval shaped articular area in proximal end (A), large sized palmar tuberosity (B), medial border (C), rough lateral surface (D) and distal extremity (E).

articulation with the single flattened proximal sesamoid bone –as recorded by Smuts and Bezuidenhout (1993) in African elephant.

The MC-2 was about twice as large as MC-1. Proximally there were 4 articular facets viz: medial for C1, proximo-medial for C2 proximo-lateral for C3 and lateral for MC-3. Similar observations were recorded in African elephant by Smuts and Bezuidenhout (1993). Out of these four articular areas the proximo-medail and proximo-lateral articular areas were separated by an oblique sagittal ridge. The proximo-medial facet was bigger, slightly concave and roughly triangular in shape broad anteriorly and narrow posteriorly area. The proximo-lateral articular facet was trapezoid in shape with narrow anteriorly and broad posteriorly. The articular facet present on medial surface was smallest and triangular in shape.

The body was large well developed and prismatic in shape. It had 3 surfaces *i.e.*, dorsal, medial and lateral surfaces and 3 borders *i.e.* medial, lateral and ventral borders (Plate 3). The dorsal surface was flattened; lateral surface was slightly convex in shape with rough area in the proximal part, while the medial surface was slightly concave and had a depression (fossa) on its proximal part. There was a tuberosity on the upper (proximal) part of ventral border. Pawan and Suraj (1999) reported a shallow vascular groove on the volar surface of metacarpus in Neel Gai. The distal extremity was nearly rounded in shape and presents the head. It was expanded. The dorsal articular area was single and in the form of undivided trochlea (nearly rounded in shape). This was demarcated from the palmer articular area by a low transverse ridge. The latter was divided by a sagittal line into two areas of which the medial one was larger than lateral one for the articulation of proximal sesamoid bones as recorded in African elephant by Smuts and Bezuidenhout (1993). The medial and lateral surfaces of the distal extremity had shallow depressions for ligamentous attachment.

The MC-3 was the largest and longest amongst all the metacarpals present in the forelimb of Indian elephant. It was quadrilateral in shape (Plate 4). The base was widest dorsally and narrowest palmarly where it ends in a prominent palmar tuberosity same as recorded in African elephant by Smuts and Bezuidenhout (1993).

The proximal articular surface consisted of four clearly defined elongated facets *viz*; medially for MC-2 followed by a large facet for C3, a smaller facet for C4 and a laterally placed facet for MC-4. Directly below the articular surfaces numerous foramina were present, especially on the lateral and medial sides as recorded in African elephant by Smuts and Bezuidenhout (1993). The articular facets were present on medial and lateral aspect of the bone. The medial articular facet was smallest among these four. The proximal articular facets present in the middle were divided by a prominent ridge into a large proximo -medial and a smaller proximo-lateral articular areas. The proximo-medial articular area was trapezoid shape, broad dorsally and narrow ventrally while the proximo-lateral articular area was nearly rectangular in shape.

The body was quadrilateral in shape compressed dorso- ventrally. In contrast to this Getty (1975) opined that the shaft of the large metacarpal was semi-cylindrical in horse. The dorsal surface was smooth and slightly concave. The ventral surface was also slightly concave and having a large but shallow fossa on its proximal aspect. The medial and lateral surfaces were flat but contain rough irregular area with numerous foramina proximally. France (2009) also



Plate 3: Left second metacarpal (anterio-lateral view) showing flattened dorsal surface (A), slightly convex lateral surface (B), medial border (C), tuberosity at the antero-lateral aspect of proximal end (D), lateral articular facet on proximal end (E) and dorsal articular area in the distal extremity (F).



Plate 4: Left third metacarpal (ventral view) showing proximal articular extremity having lateral articular facet (A), proximo-lateral articular facet (B), sagittal ridge (C), proximo-medial articular facet (D) and medial articular facet (E), slightly concave ventral surface (F), palmar articular surface divided by a sagittal ridge (G), large lateral articular facet (H) and small medial articular facet (I)

recorded small foramina in distal anterior and posterior surfaces of metacarpal of antelope.

Distally the head expands in the dorsoplamar plane and there were depressions on each side as recorded in African elephant by Smuts and Bezuidenhout (1993). The distal extremity of 3rd MC was nearly same as 2nd MC with few salient features. The distal end presents a large undivided half-moon shaped articular area on its dorsal part demarcated from the ventral part by a transverse line. The articular area on palmar surface was divided by a sagittal line into two areas for the proximal sesamoid. The lateral articular surface was slightly wider than the medial one as recorded by Smuts and Bezuidenhout (1993) in African elephant. Alrtib *et al.* (2013) recorded that in the forelimb of horse the width and depth of the medial condyles of MC-3 was greater than the lateral condyles. But the length of the lateral condyle was greater than the length of medial condyle.

Fourth metacarpal (MC-4) bone was smaller than the 3rd MC but nearly equal in length of MC- 2. At the proximal extremity there were only three articular facets for MC- 3, C-4 and MC- 5 (Plate 5). Similar observations were recorded in African elephant by Smuts and Bezuidenhout (1993). The lateral articular facet was smallest Whereas, the middle articular facet was largest in size and roughly trapezoid in shape broad dorsally and narrow ventrally.

In the proximal end the base was widest dorsally and narrowest palmarly (ventrally) and ends into a prominent palmar tuberosity.

The body was roughly quadrilateral in shape, with a flat and slightly concave dorsal surface. The medial surface was smooth on distal half and rough with numerous foramina in proximal half. The lateral surface was continued with the ventral surface. The distal 2/3rd of these surfaces was smooth, while proximal 1/3rd was rough and irregular.

The distal extremity was articular having depression on lateral and medial sides. The single dorsal articular surface was large and roughly oval shaped, separated from the palmar –surface by a transverse line. The palmar articular surface was divided into two unequal halves by a ridge; the lateral one was slightly bigger than the medial one. Damian *et al.* (2012) elucidated that in giraffe the 3rd and 4th metacarpal bones were sutured all along their length and were twice as long as those of bovines.

The fifth metacarpal bone was as bulky as MC- 4, but shorter in length (Plate 6). The proximal extremity was characterized by presence of 3 articular facets. A flattened medial facet for MC-4 and large, concave area for C-4 same as mentioned by Smuts and Bezuidenhout (1993) in African elephant. A smaller facet adjoins the latter laterally for articulation with the palmarly directed process of ulnar carpal bone.

The body was irregularly quadrilateral in shape. The dorsal surface was smooth and slightly concave in its distal half, while the proximal half of this surface was irregular in shape. A prominent tuberosity was present on the dorsomedial aspect of the proximal part of the body while the lateral part of the base bears a large, rounded prominence.

The lateral surface was formed by the continuation of the dorsal surface towards lateral side, which was rough in appearance and forming a prominent ventro-lateral border with the ventral surface. The medial surface was smooth in its distal 2/3rd part, but the proximal 1/3rd part was rough with few foramina. The ventral surface was slightly concave. Its proximal half part was elevated and rough. Shallow depressions were present on both the lateral and medial aspect of the distal articular area. The dorsal articular surface of the trochlea presents no unusual features nearly same as 4th metacarpal, but the palmer facet was larger than that of MC- 4 and was not as clearly divided into a larger lateral and a smaller medial area (Table 1).

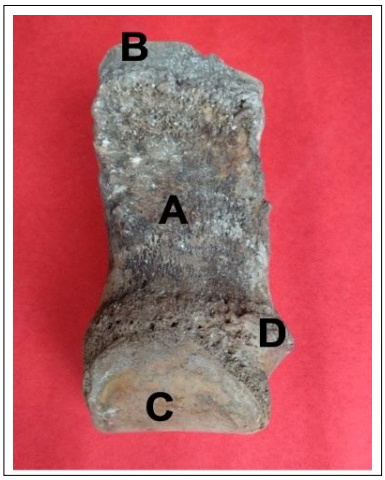


Plate 5: Left fourth metacarpal (anterior view) showing slightly concave dorsal surface(A), proximal end (B), distal end having large oval shaped dorsal articular area (C) and tuberosity on lateral aspect (D).

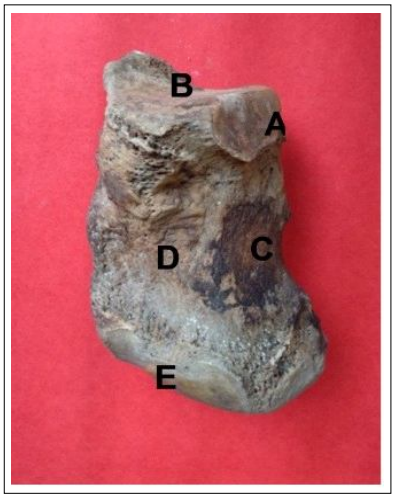


Plate 6: Left fifth metacarpal (ventro-medial view) proximal end having flattened medial articular facets (A), large concave articular area (B), medial surface(C), ventral surface (D), distal end having palmar articular facets (E).

Table 1: Various gross parameters of Metacarpals of forelimb in Indian elephant.

Parameter	MC- 1	MC- 2	MC- 3	MC- 4	MC- 5
Weight (g)	157.99±0.40	628.99±2.58	766.42±3.07	650.15±2.10	515.36±0.48
	(156.70-159.23)	(622.24-635.83)	(758.65-775.20)	(643.87-656.10)	(513.83-517.20)
Length of metacarpal (cm)	9.6±0.32	17.23±0.08	18.83±0.11	17.4±0.22	14.03±0.33
	(9-10.6)	(17-17.4)	(18.5-19.1)	(16.7-17.8)	(13.2-15)
Circumference at	18.1±1.68	25.75±0.78	28.22±0.30	25.93±0.31	26.67±0.38
proximal end (cm)	(9.8-20.3)	(24-28.2)	(27.5-29.1)	(25.2-26.9)	(25.9-27.9)
Circumference at distal	19.03±0.69	25.25±0.12	28.57±0.28	27.88±1.60	26.15±0.28
end (cm)	(16.8-20.2)	(25.2-25.6)	(28-29.5)	(25.1-33.1)	(25-26.9)
Circumference at the	12.72±0.20	17.92±0.11	19.03±0.05	19.28±0.19	22.08±0.07
mid of the Shaft	(12.1-13.2)	(17.5-18.2)	(18.9-19.2)	(18.6-19.8)	(21.8-22.3)
Width at proximal end (cm)	6.05±0.59	6.55±0.03	7.8±0.12	7.12±0.05	7.73±0.19
	(4.9-7.9)	(6.4-6.6)	(7.4-8.1)	(7-7.3)	(7-8.2)
Width at distal end (cm)	5.75±0.21	6.82±0.08	8.25±0.10	7.33±0.21	8.33±0.13
	(5.1-6.1)	(6.6-7.1)	(8-8.6)	(6.9-8)	(8-8.7)

CONCLUSION

The 3rd metacarpal bone was the longest and well developed, while the 2nd and 4th metacarpals were almost equal in length and slightly shorter than the 3rd one. The 1st metacarpal was the shortest among all the metacarpals, while the 5th metacarpal was longer than 1st but shorter than 2nd, 3rd and 4th metacarpal bones. They all presented typical features of metacarpal bones *viz.* elongated shape and approximately quadrilateral diameter. I, II, III and IV metacarpals were oblique, but V metacarpal vertically placed.

Conflict of interest

All authors declare that they have no conflict of interest.

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