Ann. For. Res. 67(1): 2024 ANNALS OF FOREST RESEARCH
ISSN: 18448135, 20652445

MORPHOMETRICAL AND RADIOGRAPHIC STUDIES ON FEMUR OF THE INDIAN ELEPHANT (*ELEPHAS MAXIMUS INDICUS)*

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ABSTRACT

The present study entitled "morphometrical and radiographic studies on femur of the Indian elephant (*Elephas maximus indicus*) was carried out in the Department of Veterinary Anatomy and Histology, College of Veterinary Science and Animal Husbandry, Mhow (M.P). This study was focused on the objectives of the morphological, morphometrical and radiographic details of the femur. The femur was strong, heavy and cylindrical shaped, directed downward in a vertical manner. It was consisted of a shaft and two extremities (proximal and distal). It was cylindrical in the middle, antero - posteriorly flattened in proximal part and prismatic distally. The shaft was flattened craniocaudally and presented two surface viz. cranial and caudal and two borders viz. medial and lateral. The nutrient foramen was present in the proximal one third of posterior surface. It had a maximum length of 104.8±3.70 cm and weight of 11.72±1.12 kg comprised of a cylindrical shaft of 85 cm, a proximal extremity of 6 cm and a distal extremity of 13 cm.
Key words : Elephant, Femur, Morphometrical, Radiography

The elephant is classified as sub ungulate (Myers, 2000). The elephant walks in an ambling way and the hind foot tread in the print of the fore foot. Their habitat, primarily the tropical forests and grasslands (Keele and Lewis, 2005) favoured for their diet (especially leaves and grass) but slow digestion due to fast ingesta passage rates (Clauss *et al.,* 2003). 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 elephant is the largest living terrestrial mammal. Usually elephant is digitigrade on the forefoot (as the hippopotamus and the tapir) and semiplantigrade on the hindfoot (Mikota *et al.,* 1994). The femur was the longest bone of the appendicular skeleton of an elephant.

The femur presented the characteristics of a long bone consisted of a shaft and two extremities (proximal and distal) (Lakshmishree *et al.,* 2017).

MATERIALS AND METHODS

For the present study femur from three Indian elephants 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. 239/6998261on dated 29.12.2020.

Some of the specimens were available at the Department of Veterinary Anatomy, College of Veterinary Science and Animal Husbandry, Mhow. Few skeletons were dug out from the ground which was 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 odor, 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 of Department of Veterinary Anatomy, College of Veterinary Science and Animal Husbandry, Mhow. The following studies were done on the collected specimens

1) **Morphological study:** The gross features of femur was observed and recorded as per their basic and specific characteristics.

2) **Morphometrical study:** The measurements such as weight, length, width, thickness etc. of femur of the Indian elephant were taken with the help of digital vernier caliper, in-elastic thread, ordinary scale and measuring tape.

3). **Radiographic study:** In the present study, radiograph of femur of hind limb were taken.

RESULTS AND DISCUSSION

The femur was the longest bone of the appendicular skeleton of an elephant. It was strong, heavy and cylindrical shaped, directed downward in a vertical manner. The femur presented the characteristics of a long bone consisted of a shaft and two extremities (proximal and distal) (Plate 1), same as reported by Lakshmishree *et al.* (2017) in Indian elephant, Abhin *et al.* (2019) in Asian elephant, Podhade *et al.* (2013) in leopard, Tomar *et al.* (2019) in Royal Bengal tiger, Onwuama *et al.* (2021a) in African lion, Shil *et al.* (2013) in Asian elephant, Onwuama *et al.* (2021b) in West African giraffe, Islam *et al.* (2018) in chital, Tefera (2011) in African elephant and Schimming *et al.* (2015) in marsh deer.

Femur, the longest bone had a maximum length of 104.8±3.70 cm and weight of 11.72±1.12 kg comprised of a cylindrical shaft of 85 cm, a proximal extremity of 6 cm and a distal extremity of 13 cm (Table 1). The length and weight of femur was recorded as 150 cm and 18 kg, respectively in Indian elephant (Lakshmishree *et al.*, 2017). The average length of femur was 22.4 cm in chital (Islam *et al.,* 2018) and 84 cm in Asian elephant (Shil *et al.,* 2013).

The circumference and width of proximal, middle/shaft and distal part of the shaft of the femur were 63.16 ± 2.01 cm and 33.50 ± 1.77 cm, 35.33 ± 1.24 cm and 14.00 ± 00 and 53.00 ± 0.81 cm and 22.66 ± 1.29, respectively (Table 1). However, the circumference and width of proximal and distal extremity were 54 cm and 25 cm and 56 cm and 22 cm in Indian elephant (Lakshmishree *et al.,* 2017), 12.30 ± 0.21 cm and 4.97 ± 0.05 cm and 14.92 ±0.63 cm and 4.61 ±0.06 cm in leopard (Podhade *et al.,* 2013), 22.84 ±0.19 cm and 8.80 ±0.1 cm and 26.64 ±0.23 cm and 7.83 ±0.09 cm in Royal Bengal tiger (Tomar *et al.,* 2019).

It was cylindrical in the middle, antero - posteriorly flattened in proximal part and prismatic distally (Plate 1). The shaft was flattened craniocaudally and presented two surface viz. cranial and caudal and two borders viz. medial and lateral (Plate 5). The Cranial surface was flattened at the proximal one third and convex at distal two third (Plate 1). This finding was similar to that of Abhin *et al.* (2019) in Asian elephant and Mariappa (1986) in Asian elephant calves.

The nutrient foramen was present in the proximal one third of posterior surface. Whereas Islam *et al.* (2018) recorded that the anterior surface had a nutrient foramen on the proximal third of the femur in chital

and Onwuama *et al.* (2021a) reported that the nutrient foramen was present on 1/3 of the shaft of femur in African lion. The caudal surface was flat, rough and narrow at middle. These finding were similar to that of Abhin *et al.* (2019) in Asian elephant. However, Podhade *et al.* (2013) noted that the caudal surface was rough in its upper third and smooth and expanded at its lower third in leopard. Whereas Ray *et al.* (1996) reported that caudal surface was flat and smooth in leopard. A less developed lesser trochanter was present in the medial side at proximal one third of posterior surface (Plate 5) same as recorded by Smuts and Bezuidenhout (1994) in African elephant. However, Sinha *et al.* (2014) in Asian palm civet and Podhade *et al.* (2013) in leopard reported that the lesser trochanter was in the form of a small tuberosity situated at the upper part of medial surface.

The medial border was rounded and its proximal end presented a rough area representing the lesser trochanter (Plate 4). This finding was similar to that of Abhin *et al.* (2019) in Asian elephant. Lateral border was smooth and concave in the upper 2/3rd and straight in distal 1/3rd same as reported by Smuts and Bezuidenhout (1994) in African elephant. However, Abhin *et al.* (2019) reported that the lateral border was smooth and straight.

The shaft was somewhat curved medially in the elephant to help in stabilizing the head in the acetabulum. A faint supra condyloid fossa was present on the distal third of the caudolateral surface. Similar finding recorded by Onwuama *et al.* (2021b) in West African giraffe and Smuts and Bezuidenhout (1994) in African elephant. Whereas, Shil *et al.* (2013) and Abhin *et al.* (2019) reported that the supracondyloid fossa was indistinct in Asian elephant. In upper 2/3rd part of the shaft the cranial, medial and lateral surfaces were continuous and smooth. The distal 1/3rd part was prismatic and had three surfaces: lateral, medial and posterior. Similar findings were reported by Podhade *et al.* (2013) in leopard and Shil *et al.* (2013) in Asian elephant

The wide proximal extremity presented the head and neck medially and greater trochanter laterally (Plate 4). The head was spherical smooth but fovea capitis was not clearly visible in this. Same was reported by Shil *et al.* (2013) in Asian elephant and Tomar *et al.* (2019) in Royal Bengal tiger and Smuts and Bezuidenhout (1994) in African elephant. This was dissimilar with cattle, sheep, goat where fovea capitis was located in the middle of the head of femur (Getty 1975). However, a shallow fovea capitis was situated posterio-medially on the head of femur in chital (Islam *et al.,* 2018). The maximum circumference of the head was 47.50±1.08 cm. whereas at constricted neck, it was 43.33±2.05 cm (Table 1). The neck was distinct same as reported by Shil *et al.* (2013) reported in Asian elephant.

Circumference at the base of the ball was 38 cm whereas at constricted neck it was 32 cm (Table 1). Tomar *et al.* (2019) in Royal Bengal tiger recorded that the mean circumference and diameter of the head was 11.66±0.21 cm and 4.74±0.08 cm, respectively. Whereas neck was prominent medially. Lakshmishree *et al.* (2017) reported that the circumference and diameter of the head was 44 cm and 20 cm, respectively in Indian elephant.

A large tuberosity called greater trochanter was situated at the lateral aspect of the proximal end and its summit was placed in lower level than the head (Plate 5). Similar finding noticed by Shil *et al.* (2013) in Asian elephant and Onwuama *et al.* (2021b) in west African giraffe. Almost to the level of neck a curved trochanteric ridge connected the greater trochanter obliquely to the lateral border on the posterior aspect, creating the trochanteric fossa (Plate 4). The trochanteric fossa was 5 cm × 6 cm in diameter and 3.00±00

cm in depth (Table 1). Similar to present study the trochanteric fossa was 4 cm deep in Asian elephant (Shil *et al.,* 2013) and 2.08 ±0.07 cm in Royal Bengal tiger (Tomar *et al.,* 2019). There was absence

of third trochanter. Similar finding noticed by Shil *et al.* (2013) and Abhin *et al.* (2019) in Asian elephant, Schimming *et al.* (2015) in marsh deer and Lakshmishree *et al.* (2017) in Indian elephant. However, Getty (1975) reported that the third trochanter was present in femur of horse.

The distal extremity was rough and had numerous foramina of unequal sizes. The distal extremity consisted of distocaudally projected two large rough condyles and a cranial trochlea. Just above the trochlea a fossa was present (supratrochlear fossa). The distal extremity presented laterally, the lateral condyle, and obliquely directed medial condyle separated by the intercondylar fossa. Cranially, it presented trochlea with two unequal ridges (Plate 2 and 3). Same was reported by Tefera (2011) in African elephant, Abhin *et al.* (2019) and Shil *et al.* (2013) in Asian elephant, Smuts and Bezuidenhout (1994) in African elephant and Lakshmishree *et al.* (2017) in Indian elephant.

The oval shaped medial condyle was larger than the elliptical lateral condyle (Plate 3). Similar finding were reported by Lakshmishree *et al.* (2017) and Shil *et al.* (2013) in elephant. However, Sasan *et al.* (2012) in camel, Schimming *et al.* (2015) in marsh deer and Islam *et al.* (2018) in chital reported that the lateral femoral condyle was much more developed than the medial one and Tomar *et al.* (2019) in Royal Bengal tiger noticed that the medial condyle was regular and more convex than the lateral condyle.

Average length and breadth of lateral and medial condyles were 12.16±0.62 cm and 8.66±0.47 cm and 15.66±0.47 cm and 10±0.40 cm, respectively (Table 1). Same parameter was recorded as 12 cm and 8 cm and 17 cm and 8 cm, respectively in Asian elephant by Shil *et al.* (2013) and 5.2 cm and 2.8 cm and 4.7 cm and 2.0 cm, respectively in chital by Islam *et al.* (2018).

Between the two condyles, a broad, oblique, rough and wide inter-condyloid fossa was present (Plate 3). Similar finding reported by Tefera (2011) in African elephant, Islam *et al.* (2018) in chital, Abhin *et al.* (2019) and Shil *et al.* (2013) in Asian elephant. In present study, the length and width of inter-condyloid fossa was 8.66±0.47 cm and 3±00 cm, respectively. Same parameters measured by Shil *et al.* (2013) in Asian elephant were 7.5 cm and 1 cm, respectively. Whereas, Tomar *et al.* (2019) reported that the mean depth of intercondyloid fossa was 2.14 ± 0.09 cm in Royal Bengal tiger.

The smooth wide trochlear groove had a length of 12.16±0.84 cm and breadth of 8.50±0.40 cm (Table 1). Same parameters were 5.1 cm and 2.4 cm, respectively in chital (Islam *et al.,* 2018) and 5 cm and 2.9 cm, respectively in Asian elephant (Shil *et al.,* 2013).

Trochlea was bounded by two parallel sagittal slightly oblique ridges -the medial and the lateral ridges; out of these two ridges the medial one was slightly upward. Medial supracondyloid tuberosity, supracondyloid fossa and extensor groove were indistinct. On the distal extremity the medial and lateral condyles, intercondyloid fossa and the trochlea were less developed indicating articulation for angular rotation. Same was reported by Tefera (2011) in African elephant and Schimming *et al.* (2015) in marsh deer. Trochanteric ridge was 14.16±0.623 cm in length (Table 1). While Lakshmishree *et al.* (2017) in Indian elephant measured the length of trochanteric ridge was 15 cm.

Radiography of femur:

In radiographic examination the x-ray was taken keeping the bone in antero- posterior position. In x-ray the cortex (white color) and medullary portion (black color) was clearly visible. The cortex was thin at the proximal and distal end and thick at the mid of the shaft of femur. Thin cortical area present in the proximal and distal end become gradually thicker and attend the maximum thickness at the mid of the

shaft. The medullary cavity was opposite to the cortical component, it was wider at the proximal and distal end and gradually become narrower towards the mid of the shaft (Plate 6). Same was reported by Kirberger *et al.* (2005) in lion and Tomar *et al.* (2019) in Royal Bengal tiger.

The maximum thickness of the cortical substances in mid of the shaft on one side was 32.62±3.34 mm while the thickness of the spongy substances (medullary cavity) was 74.76±1.82 mm in mid of the shaft. Medullary cavity was 780.77±1.46 mm long and 74.76±2.64 mm in width in the mid of the shaft. The proximal and distal part of the medullary cavity was nearly occupying the whole width of the shaft of bone. The thickness of compact substances in the proximal and distal part of the shaft was 2.20±0.12 mm. The proximal and distal extremities of the femur also show a thin layer of the compact substances. The medullary cavity of the proximal and distal part continues into marrow space of proximal and distal end of the bone.

From the present study it is concluded that femur was strong, heavy and cylindrical shaped, directed downward in vertical manner. The shaft was flattened craniocaudally and presented two surface viz. cranial and caudal and two borders viz. medial and lateral. The nutrient foramen was present in the proximal one third of posterior surface. A faint supra condyloid fossa was present on the distal third of the caudolateral surface. The wide proximal extremity presented the head and neck medially and greater trochanter laterally. There was spherical smooth head fovea capitis was not clearly visible. Almost to the level of neck a curved trochanteric ridge connected the greater trochanter obliquely to the lateral border on the posterior aspect, creating the trochanteric fossa. The distal extremity consisted of distocaudally projected two large condyles and a cranial trochlea. The oval shaped medial condyle was larger than the elliptical lateral condyle. Radiographically, the cortex was thin at the proximal and distal end and thick at the mid of the shaft of femur. The medullary cavity of the proximal and distal part was continued into marrow space of proximal and distal end of the bone.

Table 01: Various gross parameters of femur of hindlimb in Indian elephant. (Number of sample = 6)

S. No.	Parameters	Mean ± SE
1	Weight (in Kg)	11.72±1.12
2	Length (cm)	104.8±3.704
3	Circumference of proximal end (cm)	63.16±2.01
4	Circumference of distal end (cm)	35.33±1.24
5	Width of proximal part of shaft (cm)	53.00±0.81
6	Width of mid part of shaft (cm)	33.5±1.77
7	Width of distal part of shaft (cm)	14.00±00
8	Length of trochanteric ridge (cm)	14.16±0.62

9	Length of trochlear groove(cm)	12.16±0.84
10	Breadth of trochlear groove (cm)	8.5±0.40
11	Length of inter condyloid fossa(cm)	8.66±0.47
12	Width of inter condyloid fossa(cm)	3.00±00
13	Breadth of medial condyle (cm)	10.00±0.40
14	Breadth of lateral condyle (cm)	8.66±0.47
15	Length of medial condyle (cm)	15.66±0.47
16	Length of lateral condyle (cm)	12.16±0.62
17	Circumference of head (cm)	47.50±1.08
18	Circumference of neck (cm)	43.33±2.05

Plate 01: Anterior view of left femur showing, A – proximal extremity, B - shaft / body and C- distal extremity

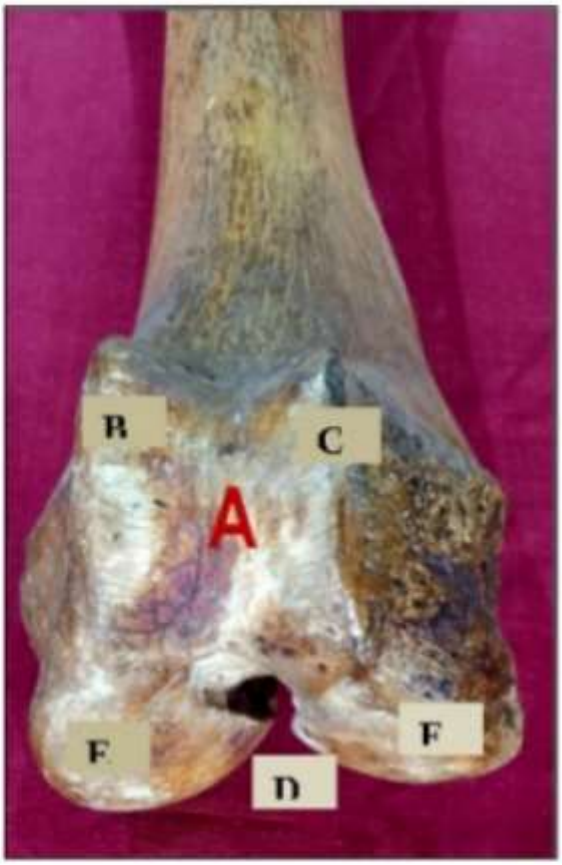

Plate 02: : Anterior view of distal end of left femur showing, A – trochlea, B- medial trochlear ridge, C- lateral trochlear ridge, D- intercondyloid fossa, E- medial condyle and F- lateral condyle

Plate 03: Posterior view of distal end of left femur showing, A - lateral condyle, B – medial condyle, C- intercondylar fossa and D- lateral supracondyloid fossa

Plate 04: Plate 04: Anterior view of proximal end of left femur showing, A - head, B - neck, C- lesser trochanter, D- trochanteric fossa, E- major trochanter and F-

Plate 05: Postero - lateral view of left femur showing, A - greater trochanter, B – lateral surface, C- posterior surface, D- head, E- medial condyle and F- lateral condyle

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