

Osteology of the thoracic limb of the African elephant (*Loxodonta africana*)

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ABSTRACT

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The forelimb bones of 8 elephants (7 adults, 1 juvenile) were studied. In addition, the bones of the digits were dissected and studied *in situ* in a mature specimen. The scapula, humerus and bones of the antebrachium (particularly the ulna) are massive in comparison to the short, relatively small bones of the manus. There are 8 carpal bones, 5 metacarpal bones and 5 digits. Digits 2–4 consist of 3 phalanges each. The 5th digit consists of 2 phalanges, while the 1st is represented by a single phalanx which is tusk-like and pointed. The distal phalanges of digits 2–4 are very small and do not articulate with the middle phalanges. The proximal sesamoids are well developed and are present on the palmar aspect of all 5 metacarpophalangeal joints. All the bones are illustrated from at least 2 aspects.

INTRODUCTION

The earliest scientific publications on the elephant skeleton date back to the early 18th century (Blair 1710 and Perrault 1734, as reported by Güssgen 1988). Several articles have appeared since, but the majority of these studies were carried out on single specimens, often from zoological gardens, due to the scarcity of material in most countries. The Indian elephant has received relatively more attention than the African. Mariappa (1986) provided the most comprehensive account, including a few line drawings of the bones of the forelimb of a fetus. Sikes (1971) gave a brief illustrated description of the bones of the forelimb of the African elephant. The present study has been undertaken to provide detailed descriptions and annotated drawings which would make identification of individual bones easy and accurate. It follows on a preliminary study by Smuts (1990). These studies are

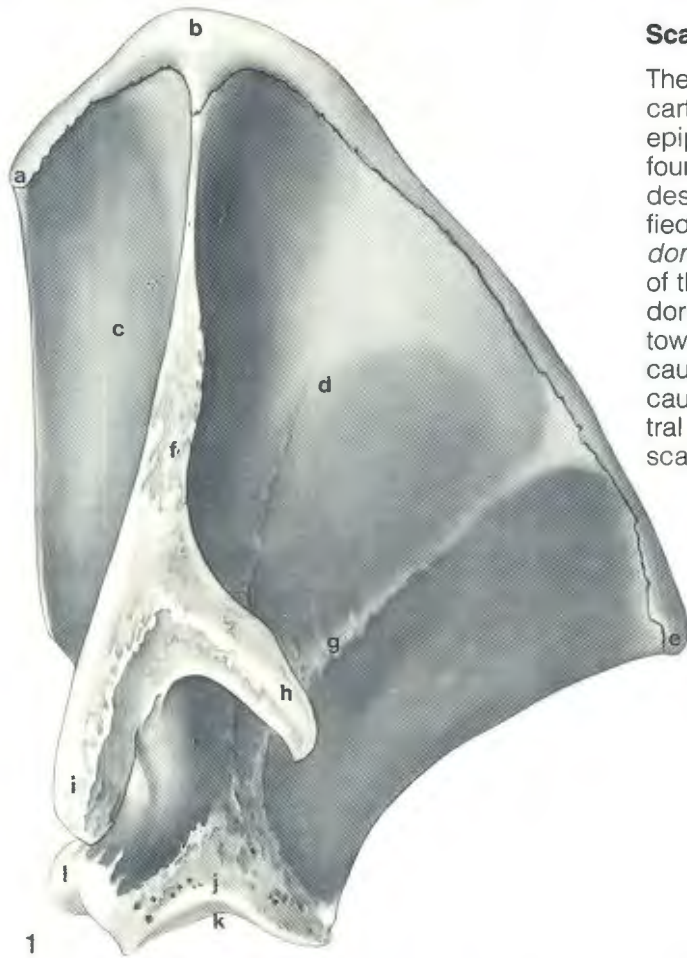
particularly relevant to the increasing importance of the African elephant as an endangered species.

MATERIALS AND METHODS

The forelimb bones of 8 African elephants were examined. Four of the adult skeletons were from the Kruger National Park, 3 from the collection of the Transvaal Museum (including an 8-month-old juvenile) and 1 from the Zoology Department of the University of Pretoria. In addition, the foot of an adult from the Kruger National Park was dissected in order to study the topography of the components of the manus. Each bone was illustrated from at least 2 aspects to ensure easy identification. The nomenclature used is based on the *Nomina Anatomica Veterinaria* (1983).

RESULTS

The skeleton of the thoracic limb is an upright pillar. The scapula, humerus and bones of the antebrachium are massive, in contrast to those of the metapodium.



Scapula (Fig. 1–3)

The scapula is irregularly triangular. The scapular cartilage ossifies at an early age and leaves an epiphyseal line. No ossification of the line was found in a 27-year-old specimen. The following description of the dorsal border includes the ossified scapular cartilage. The dorsal border, *Margo dorsalis*, forms an angular prominence at the level of the scapular spine. This prominence divides the dorsal border into a shorter, straight cranial part towards the cranial angle and a longer, sloping caudal part towards the caudal angle. The rounded caudal border is gently concave towards the ventral angle. It represents the shortest border of the scapula. The ossified cartilage is widest in the re-

FIG. 1 Left scapula. Lateral aspect

FIG. 2 Left scapula. Medial aspect

FIG. 3 Left scapula. Ventral (articular) aspect

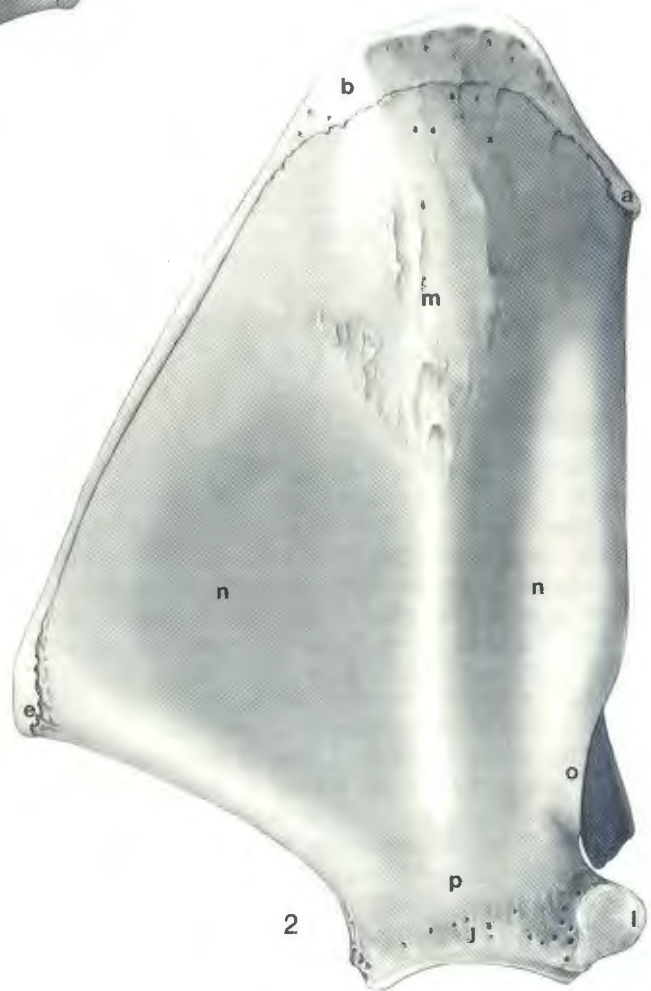
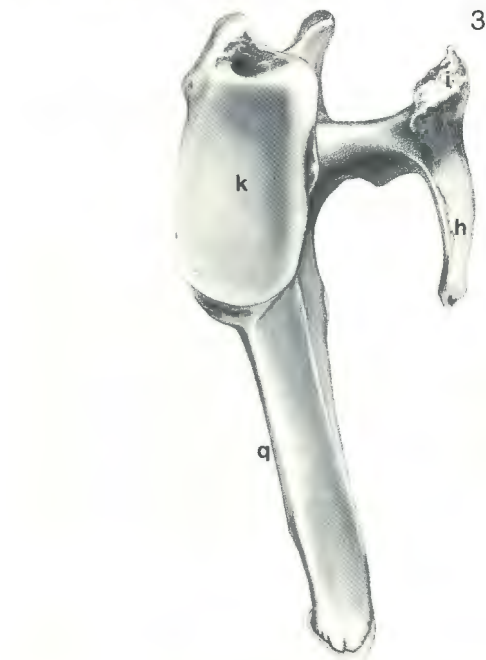


FIG. 1–3 a. *Angulus cranialis*. b. Ossified scapular cartilage. c. *Fossa supraspinata*. d. *Fossa infraspinata*. e. *Angulus caudalis*. f. *Spina scapulae*. g. Muscular ridge. h. *Processus suprahamatus*. i. *Processus hamatus*. j. *Angulus ventralis*. k. *Cavitas glenoidalis*. l. *Tuberculum supraglenoidalis*. m. *Facies serrata*. n. *Fossa subscapularis*. o. *Incisura scapulae*. p. *Collum scapulae*. q. *Margo caudalis*

gion of the scapular spine from where it narrows down to a thin band over most of the dorsal border.

Lateral surface (Fig. 1)

The lateral surface is divided into a smaller supra-spinous fossa and a larger infraspinous fossa by a prominent scapular spine, *Spina scapulae*. Proximally it is low, but it increases in height distally, to reach its maximum height towards the *Acromion*. Here a well developed slightly curved *Processus hamatus* arises, which is flattened mediolaterally. The *Processus hamatus* forms the distal continuation of the spine. There is no spinous tuberosity. The *Fossa supraspinata* is a smooth elongated concavity. The *Fossa infraspinata* is large and triangular in shape. One or 2 muscular ridges fan out from the ventral angle.

Distally, towards the *Collum scapulae*, the cranial border is notched to form the *Incisura scapulae*. Distal to the latter, is the prominent *Tuberculum supraglenoidale* which projects cranially. Muscular ridges roughen the surface adjoining the glenoid cavity, *Cavitas glenoidalis*.

Ventral angle (Fig. 2)

The glenoid cavity is elongated in a cranio-caudal direction and is only slightly concave. A smooth sagittal line divides it into a large medial and a small lateral articular surface.

Medial (costal) surface (Fig. 3)

The *Facies serrata* is represented by a rough, convex triangular area, with the apex towards the ventral angle. The *Fossa subscapularis* is separated by a smooth raised column into a large triangular caudal part, and a small cranial fossa which is convex towards the cranial border. The *Processus coracoideus* is represented by a caudal ridge of the supraglenoid tuberosity. The *Tuberculum infraglenoidale* is represented by a rough, raised area at the termination of the caudal border.

Humerus (Fig. 4–7)

The humerus is the longest and heaviest bone of the thoracic limb. It consists of a proximal and distal extremity (the epiphyses), and a shaft or diaphysis, the *Corpus humeri*.

The proximal extremity of the humerus

Caudomedially the proximal extremity presents the head, *Caput humeri*. It is elongated in a cranio-caudal plane. Laterally a flattened, elongated area is demarcated by a faint line from the major, convex part of the articular surface. The former corresponds to the lateral part of the glenoid cavity.

The head is separated from the shaft by an indistinct neck, *Collum humeri*. The major tubercle, *Tuberculum majus*, is situated laterally to the head and extends cranially to it. It consists of a relatively smaller cranial part and a larger caudal part. The latter is rounded and expanded caudally. The minor tubercle, *Tuberculum minus*, is situated medially, distal to the medial border of the head. It is oval in a sagittal plane and flattened.

Cranially to the head is the *Sulcus intertubercularis*. It is flanked laterally by the cranial part of the major tubercle and medially by the small cranial extremity of the minor tubercle. Laterally and distally to the greater tubercle there is an ovoid area for the attachment of the infraspinous muscle, the *Facies musculi infraspinati*.

The body of the humerus, Corpus humeri (Fig. 5–7)

A ridge for muscular attachment runs onto the body of the humerus from each of the tubercles. The crest from the lateral tubercle, *Crista tuberculi majoris*, is prominent and in a cranial position. It fades out towards the middle of the shaft. The crest from the minor tubercle, *Crista tuberculi minoris*, is found on the mediocaudal surface. It is represented by a rough line which ends in a rounded area, the *Tuberositas teres major*, which is either a slightly elevated or depressed area. The nutrient foramen of the shaft is situated distally to the teres major tuberosity, usually along the caudal surface. A rough elongated area in the proximal third of the lateral surface of the shaft, represents the *Tuberositas deltoidea*. It continues distally as the rounded *Crista humeri*. Proximocranially to the deltoid tuberosity is an indistinct curved line, the *Linea musculi tricipitis*, which extends to the border between the greater tubercle and the head. Caudodistal to this line is a rough, egg-shaped area, the *Tuberositas teres minor*. At the caudal end of the tricipital line a rough depression is found below the head of the humerus.

Laterally the shaft presents the spiral *Sulcus musculi brachialis*. The musculospiral groove is limited proximomedially by the humeral crest and latero-distally by the *Crista supracondylaris lateralis*.

The distal extremity, Condylus humeri (Fig. 5–7)

The articular surface, the *trochlea*, is divided by a shallow sagittal groove into a smaller medial and a larger lateral part. The medial surface of the condyle is flattened, with a shallow round depression above it. The condyle is bordered proximally by a protuberance for the attachment of ligaments. The epicondyles differ markedly in size. The *Epicondylus lateralis* is massive. It lies directly above the condyle and consists of a tuberosous distal part which flattens and narrows proximally, as far as the

distal quarter of the shaft. Numerous foramina occur in this area. The supracondylar crest, *Crista supracondylaris lateralis*, passes to the caudal surface of the shaft to form the laterodistal limit of the musculospiral groove. The *Epicondylus medialis* is much smaller than the lateral epicondyle and lies caudally and proximally to the condyle. The 2 epicondyles caudally flank a wide shallow *Fossa olecrani*. The fossa deepens directly above the condyle. The *Fossa radialis* is located on the cranial aspect. It is clearly concave laterally; less so medially.

Radius and Ulna (Fig. 8–15)

The radius and ulna constitute the skeleton of the forearm.

The ulna is much larger than the radius (ratio 5:1) and is the chief mass supporting component. The

slender radius articulates with the ulna in such a way that the proximal part is placed craniomedially, while the shaft spirals laterally over the cranial surface of the ulna to articulate distally with the medial aspect of the ulna.

Radius (Fig. 8–11)

The radius articulates with the humerus proximally to form the elbow joint and with the carpal bones distally. Proximally it also articulates with the ulna along its caudomedial surface and distally along its lateral border. The radius is divided into proximal and distal extremities with an intervening shaft or body. The proximal extremity is small and triangular in cross section, while the distal extremity is

FIG. 4 Left humerus. Proximal extremity, dorsal aspect

FIG. 5 Left humerus. Lateral aspect

FIG. 6 Left humerus. Cranial aspect

FIG. 7 Left humerus. Caudal aspect



FIG. 4–7 a. *Caput humeri*. b. *Tuberculum majus, pars cranialis*. b'. *Pars caudalis*. c. *Tuberculum minus*. d. *Sulcus intertubercularis*. e. *Collum humeri*. f. *Facies musculi infraspinati*. g. *Crista tuberculi majoris*. h. *Tuberositas deltoidea*. i. *Tuberositas teres minor*. j. *Crista humeri*. k. *Sulcus musculi brachialis*. l. *Crista supracondylaris lateralis*. m. *Epicondylus lateralis*. n. *Fossa radialis*. o. *Trochlea humeri*. p. *Epicondylus medialis*. q. *Fossa olecrani*. r. *Tuberositas teres major*

FIG. 8 Left radius and ulna. Proximal aspect

FIG. 9 Left radius and ulna. Distal aspect

FIG. 10 Left radius. Craniomedial aspect

FIG. 11 Left radius. Caudolateral aspect

FIG. 12 Left ulna. Lateral aspect

FIG. 13 Left ulna. Medial aspect

FIG. 14 Left ulna. Cranial aspect

FIG. 15 Left ulna. Caudal aspect



FIG. 8–15 a. *Fovea capitis radii*. b. *Processus coronoideus lateralis*. c. *Processus coronoideus medialis*. d. *Processus anconeus*. e. *Tuber olecrani*, e'. *Olecranon*. f. *Facies articularis carpea* (radius). g. *Processus styloideus radii*. h. *Facies articularis carpea* (ulna). i. *Processus styloideus ulnae*. j. *Caput radii*. k. *Collum radii*. l. *Tuberositas radii*. m. *Corpus radii*. n. *Circumferentia articularis*. o. *Incisura ulnaris*. p. *Incisura trochlearis*. q. *Corpus ulnae*. r. *Circumferentia articularis* for radius. s. *Incisura radialis*. t. *Caput ulnae*

expanded and larger. The radius is curved in a lateral direction along its longitudinal axis.

The *Fovea capitis radii*, on the proximal surface of the radial head is shaped like an isosceles triangle, with the apex facing laterally. It is lightly concave in the region of the apex and convex towards the base. The articular surface is continued along the caudomedial surface of the head to form a *Circumferentia articularis* for articulation with the ulna.

The neck, *Collum radii*, is the constricted segment directly below the head. The cranial surface is rough for muscular attachment, representing the *Tuberositas radii*. Caudally the neck is rough and irregular for attachment to the ulna.

The shaft, *Corpus radii*, is continued distally from the neck. It is bilaterally compressed in the proximal third of its length. Distal to the area representing the radial tuberosity, an elongated rough area occurs on the cranial surface. Towards the middle portion of the shaft the bone is rounded cranially, but in the distal half it is flattened craniolaterally. The medial surface of the shaft is concave and rough. The distal third of the shaft expands in a craniomedial and caudolateral direction.

The cranial surface of the shaft, *Facies cranialis*, presents an irregular outline. This is due to the outward curve along its axis and the shape of the shaft. The cranial border of the shaft is represented by a longitudinal ridge. The ridge fades out along the convex portion of the shaft.

The caudal surface of the shaft, *Facies caudalis*, has an irregular appearance. There is a prominent area for muscular attachment along its proximal half which has a lateral slope. This rough area is proximally separated from the neck by an oblique vascular groove. The distal half of the caudal surface of the shaft presents a narrow surface which is demarcated laterally by a fairly sharp line and medially by a rounded border. The caudal surface of the shaft widens towards the distal epiphysis.

The lateral surface of the shaft, *Facies lateralis*, presents the lateral part of the area for muscular attachment described in caudal view. The nutrient foramen of the shaft is situated between the proximal and middle thirds of the shaft, directly above a rough longitudinal area over the caudal side of the surface. The distal region expands towards the epiphysis.

The medial surface of the shaft, *Facies medialis*, presents a large rough area along the proximal half.

The *Trochlea radii* forms the distal extremity of the bone. It is the largest part of the radius and is irregularly triangular in shape with the base directed caudally. The articular surface, *Facies articularis carpea*, is much more extensive caudally

than cranially. Caudally the articular surface is convex in both directions and stretches almost up to the epiphyseal line. Laterally this caudal part extends on the flattened lateral surface. Directly distal to the epiphyseal line, an egg-shaped articular surface, the *Incisura ulnaris*, occurs for articulation with the distal end of the ulna. Medially, the *Processus styloideus* is represented by 2 rough convexities, separated from each other by a slight depression. The proximal convexity lies directly below the epiphyseal line, while the distal convexity lies directly above the articular surface. There are no clearly defined grooves on the dorsal surface. Numerous foramina occur along the non-articular surfaces of the distal extremity. The largest foramina are found laterally, where the bone is very rough.

Ulna (Fig. 8, 9, 12–15)

The ulna of an adult is approximately 5 × heavier than the radius. For descriptive purposes it can be divided into a body or shaft and 2 extremities. The proximal extremity, the *Olecranon*, projects beyond the radius. The *Tuber olecrani* is massive, especially caudolaterally. The dorsal surface of the olecranon presents a broad, caudally convex surface which narrows towards the *Processus anconeus*. The surface is rough and contains numerous foramina. Below the *Tuber olecrani* the bone is bilaterally compressed to form a fairly sharp caudal border which is continuous with the caudal border of the shaft.

The undivided trochlear notch, *Incisura trochlearis*, faces cranially and its proximal part is as wide as it is high. It is concave in an axial plane and gently convex in a mediolateral plane. The proximally placed *Processus anconeus* is wide and rounded. The trochlear notch is continued distally by the medial and lateral coronoid processes, *Processus coronoideus medialis* and *Processus coronoideus lateralis*. The medial process is bigger than the lateral one and both articular surfaces are slightly concave.

The shaft, *Corpus ulnae*, is flattened cranially. Proximally it is triangular in cross section, while it gradually assumes an almost square shape towards the distal extremity. The cranial surface is characterised by a rough area for attachment to the radius, extending from the proximal end in a disto-medial direction. There is a deep concavity proximally, the *Incisura radialis*, and an articular surface above it along the cranial surfaces of the coronoid processes. The articular area on the lateral side is larger than that on the medial side. The lateral surface of the shaft is marked by a fairly sharp, straight cranial border and a sloping concave caudal border which narrows down from the olecranon towards the shaft. A clear line runs along the lateral

border from the vicinity of a ligamentous tuberosity on the lateral coronoid process. It runs obliquely in a caudadistal direction, fading out towards the distal extremity. The caudal border of the shaft is sharp proximally. Towards the middle of the shaft it becomes rounded. The caudal surface is continuous with the medial and lateral surfaces.

There is an elongated rough area over the third quarter of the caudal surface of the shaft adjoining the medial surface. The nutrient foramen of the shaft is small and its position is variable. The medial surface contains the distal continuation of the rough area for the radius. This rough area widens towards the epiphysis. A longitudinal vascular groove, which bifurcates in the distal quarter, is clearly visible.

The distal extremity is represented by the ulnar head, *Caput ulnae*. It presents a roughly oval articular surface, *Circumferentia articularis*, for articulation with the radius. Directly distally to the articular surface for the radius is an articular surface for the intermediate carpal bone. The articular surface for the carpal bones, *Facies articularis carpea*, is irregularly shaped. The distal extremity of the ulna articulates mainly with the ulnar carpal bone, but also caudally with the accessory carpal bone. The articular surface is wider towards the caudal aspect where it continues around the caudal border. Caudally the articular surface is convex in a cranio-caudal plane, while the cranial part is flat and round in outline. There is a lateral prominence, caudally below the epiphysial line, representing the *Processus styloideus*. Cranial to the styloid process a groove occurs which is bordered cranially by a rough tuberosous area.

Numerous foramina are present in the surface of the bone in this region.

Carpus (Fig. 16–23)

The carpal bones are 8 in number and are arranged in 2 rows. The proximal row consists of the radial, intermediate, ulnar and accessory carpal bones, while the distal row consists of carpal bones I–IV.

Os carpi radiale (Fig. 16)

The radial carpal bone is the most medial bone in the proximal row. It is a flattened bone which is placed obliquely in such a way that it faces medio-dorsally. Proximally the bone is narrower than distally. It articulates proximally with the radius, laterally by means of a proximal and a distal facet with the intermediate carpal bone and distally with the 2nd and 3rd carpal bones. A relatively large space or canal occurs between the two articulations between the radial and intermediate carpal bones.

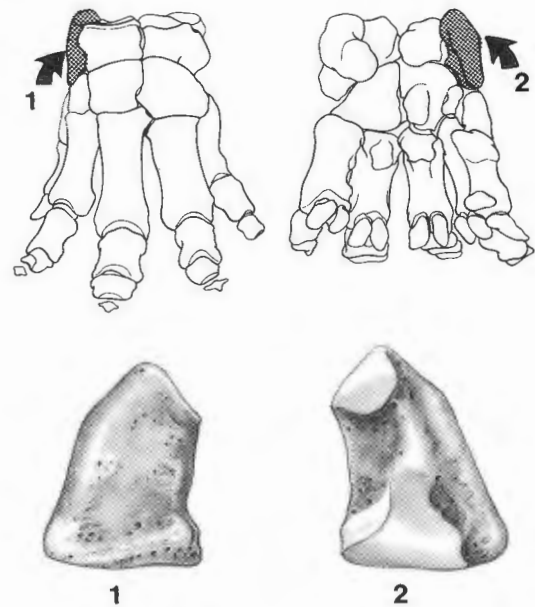


FIG. 16 Left radial carpal bone. Arrows indicate aspects illustrated

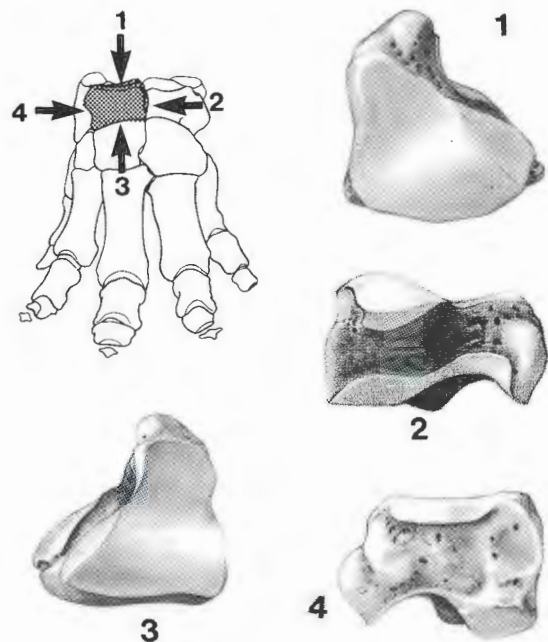


FIG. 17 Left intermediate carpal bone. Arrows indicate aspects illustrated

Os carpi intermedium (Fig. 17)

The intermediate carpal bone is wedge-shaped with the base facing dorsally. It bears a rounded tuberosity palmarly. Its proximal articular surface is saddle-shaped and articulates with the radius. Dorsolaterally an oblique continuation of this surface also articulates with the ulna and with the ulnar carpal bone. Along the distal border of the lateral surface, a parallel area occurs for articulation with

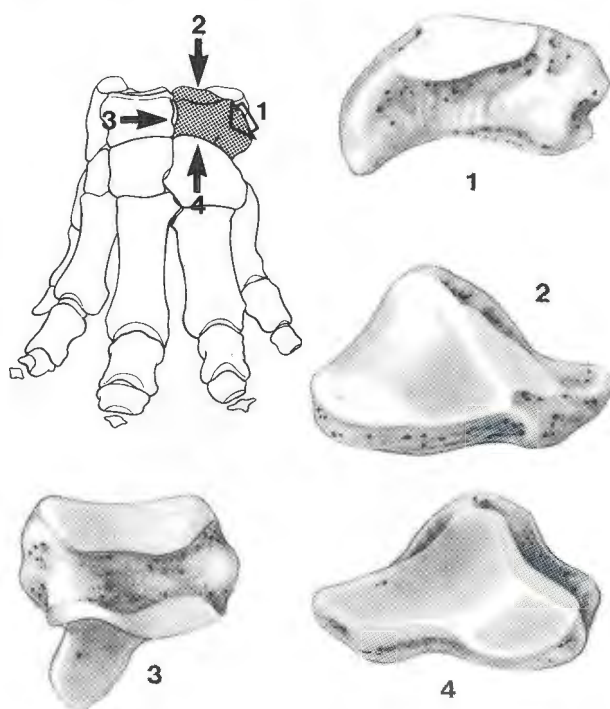


FIG. 18 Left ulnar carpal bone. Arrows indicate aspects illustrated

the contiguous surface of the ulnar carpal bone. Over the medial surface there are 2 facets for the radial carpal—1 proximally and the other distally. The distal articular surface is also saddle-shaped like the proximal, but the curvatures are far more pronounced. It articulates with the 3rd carpal bone.

***Os carpi ulnare* (Fig. 18)**

The ulnar carpal bone is the largest bone of the proximal row and is situated on the lateral side. It is roughly triangular in shape, with a prominent elongation pointing palmarly and laterally. On the palmar surface of the base of this projection, a large oval articular facet occurs for the accessory carpal bone. The proximal articular surface is saddle-shaped. The distal surface consists of a quadrilateral medial part, also saddle-shaped, and a flattened lateral projection. It articulates with *Os carpale IV*. Medially and distally it articulates with the intermediate carpal bone, while a small elongated facet, facing dorsopalmarly, articulates with the 5th metacarpal bone.

***Os carpi accessorium* (Fig. 19)**

The accessory carpal bone articulates with the palmar surface of the ulnar carpal and with the ulna. An elongated tuberos process projects from its articular base in a caudopalmar direction. There is a smooth transverse groove along the medial surface of this projection. The rest of the non-articular

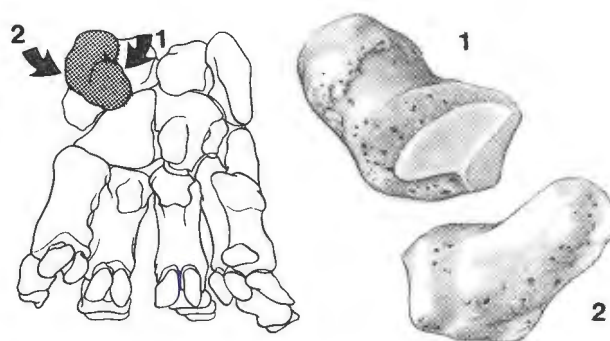


FIG. 19 Left accessory carpal bone. Arrows indicate aspects illustrated

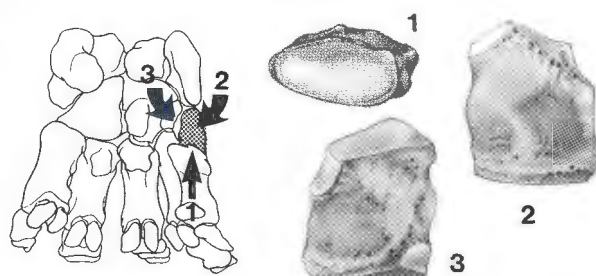


FIG. 20 Left *Os carpale I*. Arrows indicate aspects illustrated

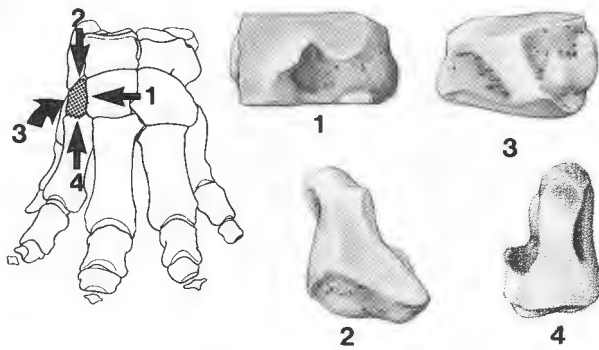
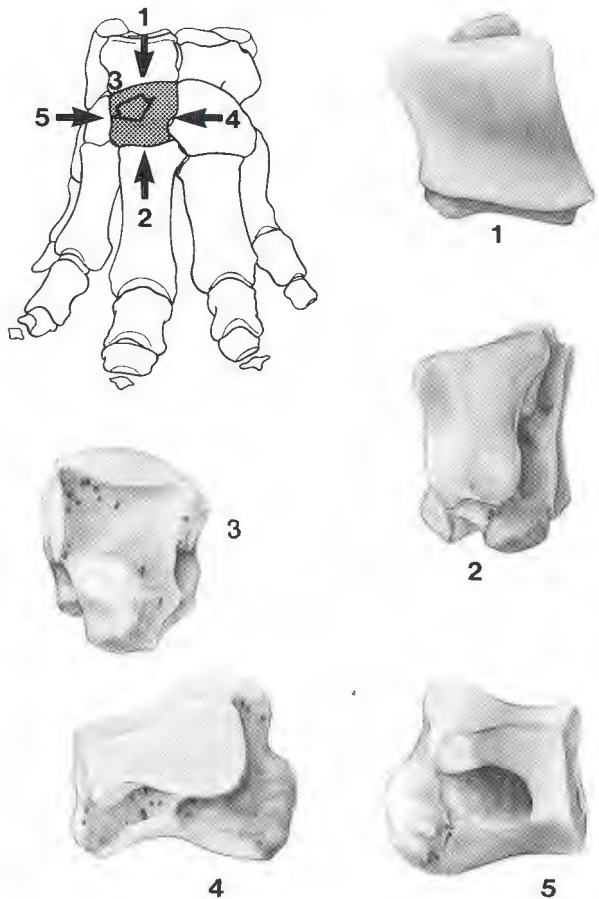
surfaces are rough and contain numerous small vascular foramina.

***Os carpale I* (C1) (Fig. 20)**

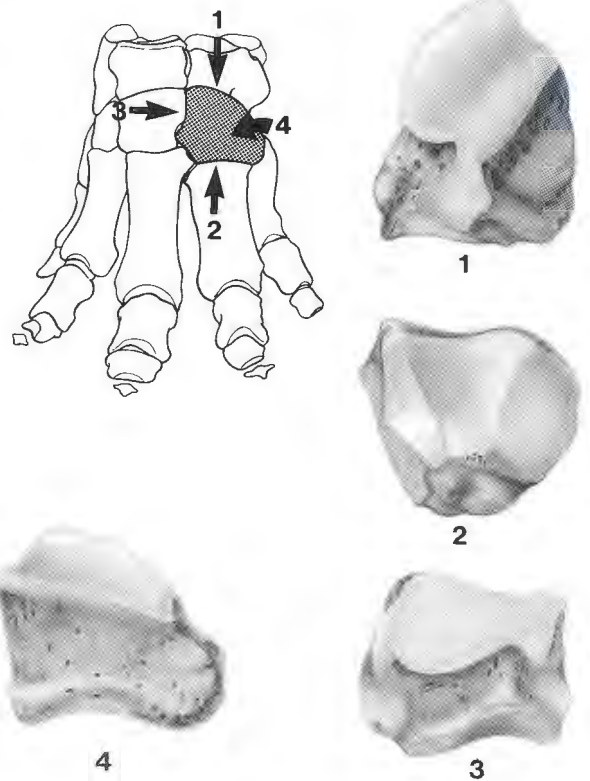
The 1st carpal bone of the distal row is a flattened, roughly quadrilateral bone, in contrast to the more bulky form of the others. It projects medially and is pointed distopalmarly. Its medial surface is more or less flattened and rough, while the lateral surface is more concave and contains numerous nutrient foramina. Proximally a large facet occurs for articulation with *Os carpale II*. Proximally and distally to this facet, smaller facets are present for articulation with the radial carpal and metacarpal II respectively. The distal articular surface is oval in shape and articulates with the 1st metacarpal.

***Os carpale II* (C2) (Fig. 21)**

This is the 2nd smallest of the carpal bones and it is roughly triangular in shape with a blunt palmar projection. Laterally it articulates with the 3rd carpal bone by means of a large, curved bifaceted proximal area and a small distal facet. Below the proximal facets the surface is excavated and rough. The flattened proximal extremity articulates with the medial part of the radial carpal. The distal extremity is roughly T-shaped. It articulates with part of the 2nd metacarpal bone, while about half of the medial surface of the bone consists of a quadrilateral facet for the 1st carpal. The dorsal surface is rough and foraminous.

FIG. 21 Left *Os carpal II*. Arrows indicate aspects illustratedFIG. 22 Left *Os carpal III*. Arrows indicate aspects illustrated***Os carpal III* (C3) (Fig. 22)**

The 3rd carpal bone is almost square, when viewed from the proximal aspect. The articular surface is clearly saddle-shaped for contact with the intermediate carpal. The dorsal surface is flat and rough with foramina particularly evident towards the extremities. The distal articular surface is divided by a sagittal line into a small medial and a large lateral area for the 2nd and 3rd metacarpals respectively. The medial surface is character-

FIG. 23 Left *Os carpal IV*. Arrows indicate aspects illustrated

ised by a deep rough central concavity with foramina, surrounded proximally, dorsally and distally by articular surfaces for the 2nd carpal. On the lateral aspect there is a large articular surface proximally, and a small distal facet for *Os carpal IV*. The palmar surface is flat proximally, but bears a prominent tuberosity distally.

***Os carpal IV* (C4) (Fig. 23)**

This bone forms the lateral component of the distal row. Its proximal articular surface is for the ulnar carpal bone, while the distal articular surfaces accommodate part of the 3rd metacarpal, and metacarpals 4 and 5. Laterally the bone is elongated and presents a rounded tuberosity. The palmar surface is roughly triangular with large vascular foramina towards the proximal articular surface. On the medial aspect there is an extensive flask-shaped articular facet proximally, and a small facet distally, for the 3rd carpal. The surface between the 2 facets is a rough concavity.

Metacarpus (Fig. 24–27)

There are 5 rays in the metapodium of the forelimb, *Ossa metacarpalia 1–V*. The 3rd is the best developed, followed by the 4th, 5th and 2nd metacarpals. The 1st metacarpal is much smaller than the

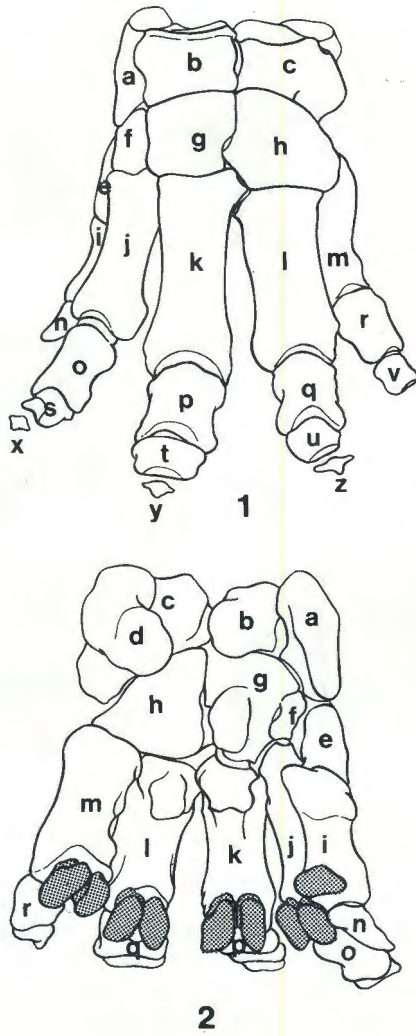


FIG. 24 Left manus. Dorsal (1) and palmar (2) aspects

a. Radial carpal bone. b. Intermediate carpal bone. c. Ulnar carpal bone. d. Accessory carpal bone. e. *Os carpalae I*. f. *Os carpalae II*. g. *Os carpalae III*. h. *Os carpalae IV*. i-m. *Ossa metacarpalia I-V*. n-r. Proximal phalanges of digits 1-5. s-v. Middle phalanges of digits 2-5. x-z. Distal phalanges of digits 2-4. Proximal sesamoid bones are shaded

others. They all represent typical features of metacarpal bones, viz. an elongated shape and an approximately quadrilateral diameter.

The *1st metacarpal bone*, Mc1 (Fig. 25), is the smallest and most medial. It is expanded at both ends. Proximally the base bears a large flat elongated articular facet for the first carpal bone. There is no articulation with Mc2. Mediopalmarly the base expands to form a prominent palmar tuberosity. The body (corpus) is slightly constricted towards its middle. Proximally, on its dorsal and medial aspects a rough elevated area occurs for ligamentous attachment. The head expands to form roughened surfaces dorsally and on each side for the

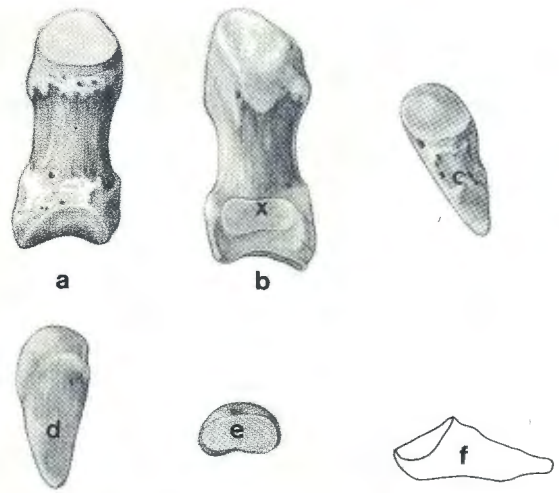


FIG. 25 Metacarpal bone I and digit 1 with single phalanx and single proximal sesamoid bone

a. Dorsal aspect of Mcl. b. Palmar aspect of Mcl. x. Articular surface for proximal sesamoid bone. c, d. Dorsal and palmar surfaces of phalanx. e. Articular surface of proximal sesamoid bone. f. Lateral outline of phalanx

attachment of ligaments. The trochlea presents 2 articular areas which are divided by a transverse line. The dorsal area articulates with the single tusk-like phalanx, while the palmar facet with a transverse, elongated, smooth articular surface along its proximal half is for articulation with the single, flattened proximal sesamoid bone.

The *2nd metacarpal bone*, Mc2 (Fig. 26), is about twice as large as Mc1. Proximally there are 4 articular facets: medially for C1, proximomedially for C2, proximolaterally for C3 and laterally for Mc3. A prominent tuberosity occurs on the palmar aspect of the base. The body is flattened dorsally, while the lateral surface is rough proximally for ligamentous attachment. The medial border forms an oblique crest sloping dorsopalmarly. The distal extremity represents the head, *Caput*. It is expanded and the trochlea consists of a large undivided dorsal facet which is demarcated by a low ridge from the palmar facet. The latter is divided by a sagittal line into 2 areas of which the medial is the largest. The proximal sesamoids articulate here. The medial and lateral surfaces of the head have shallow depressions for ligamentous attachment.

The *3rd metacarpal bone*, Mc3 (Fig. 26), is the largest of the series. The base is widest dorsally and narrowest palmarly where it ends in a prominent palmar tuberosity. The proximal articular surface consists of 4 clearly defined elongated facets: medially for Mc2, followed by a large facet for C3; a smaller facet for C4 and a laterally placed facet for Mc4. Directly below the articular surfaces numerous foramina occur, especially on the sides. The

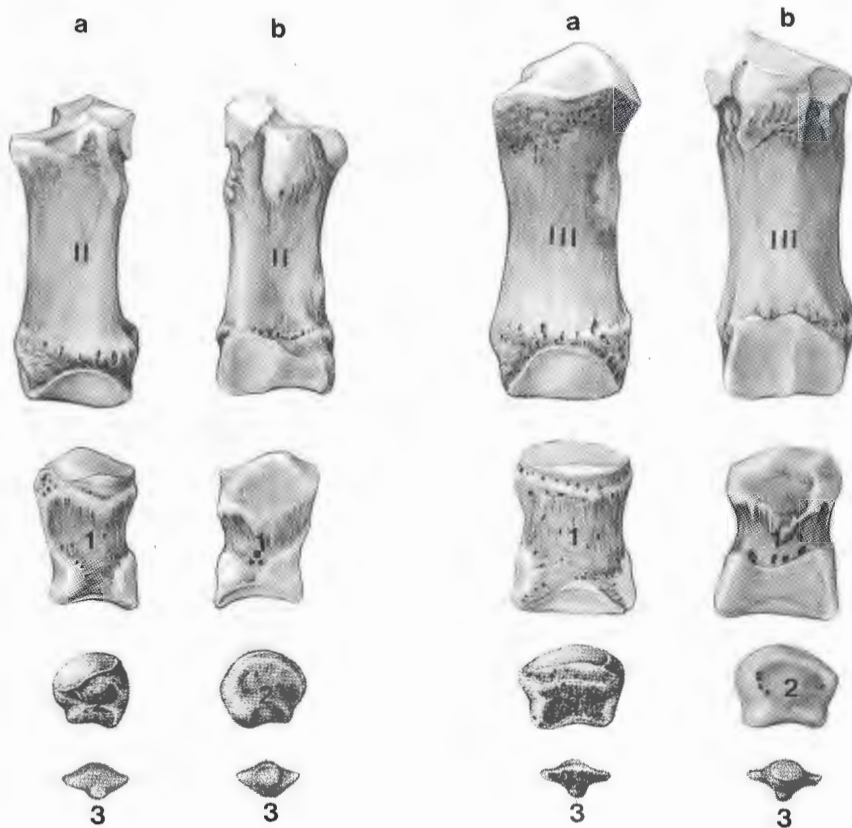


FIG. 26 Metacarpal bones 2 and 3 with corresponding phalanges. Dorsal aspects—*a*, and palmar aspects—*b*. 1–3. Proximal, middle and distal phalanges

body is flattened and slightly concave dorsally. The medial and lateral surfaces of the body contain rough irregular areas proximally. Distally the head expands in the dorsopalmar plane and there are depressions on each side as well as numerous foramina. The trochlea presents a large undivided dorsal part, demarcated from the palmar part by a transverse line. The palmar articular surface is divided by a sagittal line into 2 areas for the proximal sesamoids. The lateral articular surface is slightly wider than the medial.

The *4th metacarpal bone*, Mc4 (Fig. 27), is smaller than the 3rd, but generally resembles it in shape. The differences are as follows: there are only 3 proximal facets (for Mc3, C4 and Mc5 respectively); distally the 2 facets for the proximal sesamoids on the palmar side of the trochlea differ markedly in size, the lateral being approximately twice as wide as the medial; the flattened dorsal surface of the body tends to be slightly concave.

The *5th metacarpal bone*, Mc5 (Fig. 27), is as bulky as Mc4, but shorter. It is characterised by 3 articular facets proximally: a flattened medial surface for Mc4 and a large concave area for C4. A smaller facet adjoins the latter laterally for articulation with

the palmarly directed process of the ulnar carpal bone. A prominent tuberosity is present on the dorsomedial aspect of the proximal part of the body, while the lateral part of the base bears a rounded prominence. The proximal half of the palmar surface is elevated and rough. The dorsomedial border expands to form a prominence directly above the trochlea. The dorsal articular surface of the trochlea presents no unusual features, but the palmar facet is larger than that of Mc4 and is not as clearly divided into a larger lateral and a smaller medial area.

The digits (Fig. 25–28)

There are 5 digits, of which only the 2nd, 3rd and 4th consist of 3 phalanges each. It must be noted that the distal phalanx, when present, does not articulate with the middle phalanx.

The *1st digit* consists of 1 phalanx only. It is tusk-like, with a round base which narrows down to a distal point. The oval, slightly saddle-shaped articular surface is for the dorsal facet on the trochlea of Mc1. The central part of the dorsal surface forms a depression containing foramina. It is surrounded by a low crest, while the apex is smooth. The palmar

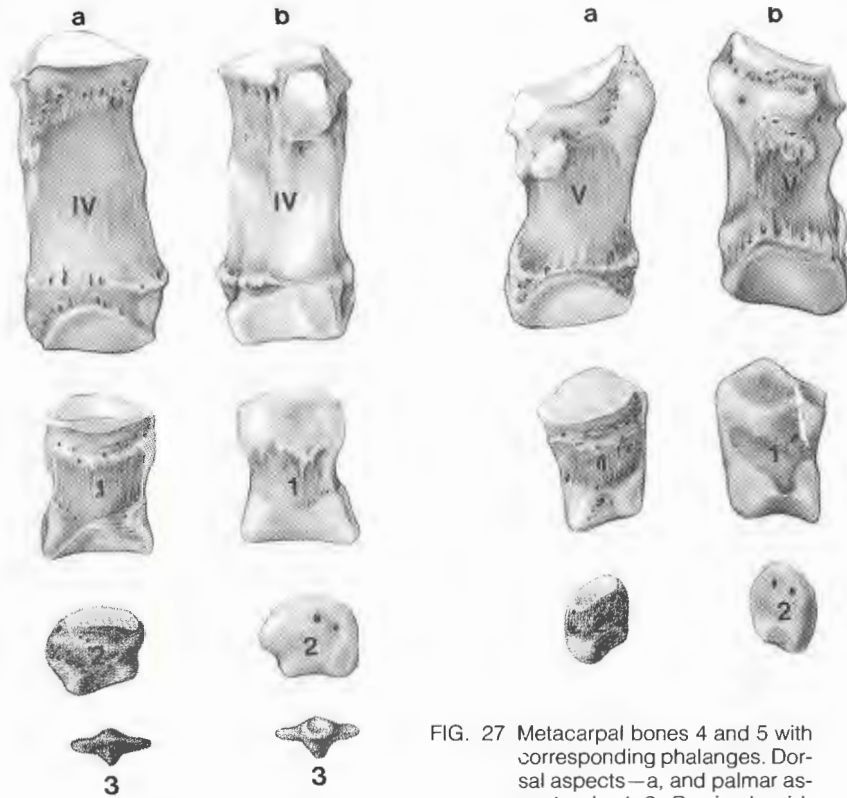


FIG. 27 Metacarpal bones 4 and 5 with corresponding phalanges. Dorsal aspects—*a*, and palmar aspects—*b*. 1–3. Proximal, middle and distal phalanges

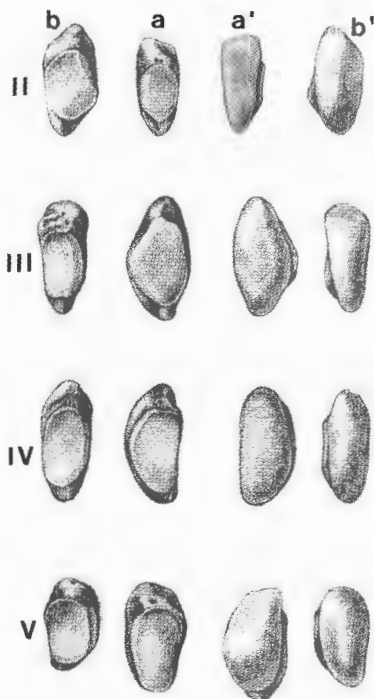


FIG. 28 Proximal sesamoid bones of digits 2–5. *b*. Articular aspects of abaxial sesamoid bones. *b'*. Palmar aspects of abaxial sesamoid bones. *a*. Articular aspects of axial sesamoid bones. *a'*. Palmar aspects of axial sesamoid bones

surface is relatively smooth and convex from side to side. When viewed from the side the bone is slipper-shaped.

The *proximal phalanges* of the digits 2–5 are more or less similar in shape, with that of digit 3 being the largest, followed by digits 4, 2 and 5. The main difference between digits 2 and 5 is the axial curve of the latter. Each digit consists of a base with a single round, slightly concave proximal articular surface, a body which presents dorsal, medial, palmar and dorsal surfaces and a distal, undivided trochlea. The latter is convex in a dorsopalmar plane in digits 3 and 4; concave in digits 2 and 5. In palmar view each bone presents a proximal, relatively smooth, elevated area, while the medial and lateral surfaces are flattened on either side of the trochlea.

The *middle phalanges* of digits 2–5 are considerably smaller than the proximal phalanges. In digits 3 and 4 this bone is larger than in digits 2 and 5. The middle phalanx of *digit 2* is shaped in such a way that the lateral border is convex, while the medial border is shorter and concave. The proximal articular facet is oval in outline and slightly saddle-shaped. The dorsal surface of the bone is rough and contains numerous foramina. The distal extremity is narrower than the proximal, is not

covered with articular cartilage and contains 2–5 foramina. The palmar surface is relatively smooth and rounded, except distally where there is a depression. The middle phalanx of *digit 3* is the only bone in the series which is bilaterally symmetrical. The large, oval articular surface is slightly concave dorsopalmarly, the distal extremity is relatively smooth and slightly concave from side to side, but this is not a typical articular surface. The dorsal surface of the bone contains numerous foramina, a transverse line proximally and a depression centrally, flanked by a medial and lateral tubercle. There is a flattened area on each side for ligamentous attachment. The palmar surface of the bone has a wide, smooth, sloping central area. One or 2 large foramina and a variable number of smaller ones may occur in this surface. The middle phalanx of *digit 4* differs from that of *digit 3* in the following aspects: it is irregular in shape, with its longitudinal axis sloping axially; is wider proximally; the smaller distal extremity slants from lateral to medial. The middle phalanx of *digit 5* is the smallest of the series and is almost quadrilateral in shape. The proximal articular surface is oval in outline and gently saddle-shaped or flat. The distal extremity ends in a blunt point directed axially.

Digits 2–4 possess a small *distal phalanx* each. The unusual shape, namely a pointed process on each side, and a 3rd, shorter distally directed tubercle, suggests the possibility that this bone represents a fused distal phalanx and sesamoid. On palmar view there is a smooth round central area, flanked by relatively long horizontal processes. The bone of the 4th digit has the longest processes. These bones do not articulate with the middle phalanges. They are firmly attached to the corium of the respective nail/hoof and are separated from the middle phalanges by a thick cushion of connective tissue (Fig. 29).

The *proximal sesamoid bones* (Fig. 24, 25 & 28) are found in pairs which articulate with each other, on the palmar facets of the trochlea of metacarpals 2–5. A single flattened sesamoid bone is found in the same position on metacarpal I. The lateral sesamoid bone is larger than the medial bone in digits 3–5. In digit 2 however, it is the medial (abaxial) sesamoid which is bigger. The largest sesamoid is the lateral (abaxial) of digit 5. The relative size of each sesamoid corresponds to the articular facets on the trochlea of the corresponding metacarpal bone.

DISCUSSION

The descriptions of the proximal bones of the forelimb of the African elephant in the available literature are very brief, but our findings are in agreement with Flower & Lydekker 1891, as reported by

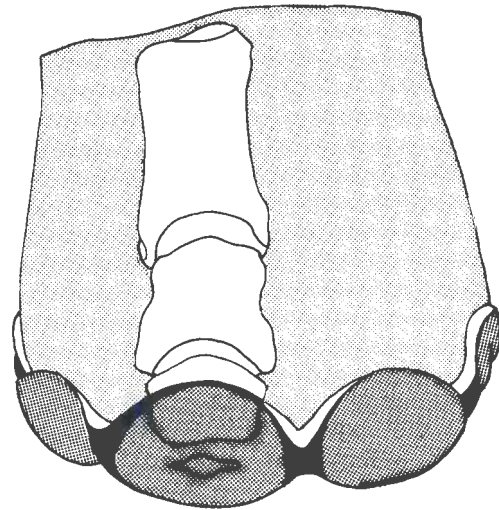


FIG. 29 Topography of digit 3. Semi-schematic rendering of dorsal view

Güssgen 1988 and Sikes 1971. The constant presence of the ossified scapular cartilage in young adults and older animals has not been reported before.

The presence of 8 carpal bones was described by early workers (Waldhofer 1889; Baur 1889–1900; Schlesinger 1912 and Grawlenko 1924 as reported by Güssgen 1988). The bones of the manus were also described and photographed by Sikes (1971). Considerable confusion marks the descriptions of the phalanges. We believe this to be due to the atypical position and possible function of the distal phalanges of digits 2–4. They do not articulate with the middle phalanges, are relatively very small and are attached to the respective nails. Our numerical findings of the phalanges correspond to Virchow (1910a) and Eales (1928–1929) as reported by Güssgen (1988).

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